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THE NUMERICAL ANALYSIS OF AIR COMBAT ENGAGEMENTS DOMINATED BY M--ETC(U)
JUN 77 W R SIMPSON, R A OBERLE

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Technical Memorandum

THE NUMERICAL ANALYSIS OF AIR COMBAT ENGAGEMENTS DOMINATED BY MANEUVERING PERFORMANCE

by

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and

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20 June 1977

DEPARTMENT OF THE NAVY
NAVAL AIR TEST CENTER

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An analysis capability has been developed for use by the training and 'test and evaluation' communities to quantify air combat maneuvering engagement outcomes. Details of this analysis capability in the form of computer programs for producing analytic engagement data are presented. Results from a sample test data base are presented to illustrate analysis and conclusion forming methods. The conclusions from the sample data set are not intended to represent actual strategic decisions but are exemplary only. These analytical programs have been implemented at NAVAIRTESTCEN (SA43), the Naval

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Weapons Center (Code 4072), the Air Combat Maneuvering Range (via COMFITAEWWINGPAC), and the Center for Naval Analyses.

PREFACE

Recent emphasis on Air Combat Maneuvering (ACM), including the congressionally directed AIMVAL/ACEVAL trials, has created interest in developing methods of analysis to assess aircraft capabilities, pilot proficiency, force requirements, etc. Several methods are in use by industry, but many emphasize specific aircraft characteristics and are therefore limited in their application. This report describes an ACM analysis method developed by Mr. W. S. Stewart (Naval Weapons Center), Dr. R. A. Oberle (Center for Naval Analyses), and Mr. W. R. Simpson (NAVAIRTESTCEN). Several aspects of these analysis methods are being explored jointly by the Navy Fighter Weapons School, the Naval Weapons Center, the Center for Naval Analyses, and NAVAIRTESTCEN. These analysis techniques have been implemented at NAVAIRTESTCEN, the Naval Weapons Center, the Air Combat Maneuvering Range, and the Center for Naval Analyses. The NAVAIRTESTCEN participation was funded by the Joint Technical Coordinating Group/Munitions Effectiveness chaired by the Army Materiel Systems Analysis Agency, Aberdeen, Maryland. Assistance in the application of these techniques to specific problems of air combat is available through:

a. NAVAIRTESTCEN (SA43)

b. NAVWPNCEN (Code 4072)

c. Naval Air Combat Maneuvering Range (CNA Rep to COMFITAEW-WINGPAC)

d. Center for Naval Analyses

APPROVED FOR RELEASE

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INTRODUCTION

BACKGROUND

1. The development of adequate analysis techniques in the area of Air Combat Maneuvering (ACM) is vital to the definition of the mission effectiveness of fighter aircraft, performance devices installed on fighter aircraft, and aircraft weapon systems. For the most part, however, the development of ACM testing and analysis procedures has lagged other evaluation areas such as air-to-ground or aircraft performance and flying qualities testing. Beginning in late 1971, the Commander, Operational Test and Evaluation Force initiated development of stochastic ACM analysis techniques. This effort resulted in the finite state maneuver conversion model (reference 1) and its application to the ACM evaluation of a thrust vectored attack aircraft as part of CNO Project P/V-2 (reference 2). An additional application of the maneuver conversion model to an in-flight ACM evaluation was made at NAVAIRTESTCEN for the F-11A thrust vector control system (reference 3). Following these applications, the finite state maneuver conversion model was extended by the introduction of a continuous time/continuous state performance index (reference 4). The performance index scales the offensive value of the interaircraft dynamics via the product of angle, range, and energy penalty functions. Numerical analysis of the stochastic process resulting from the application of these two evaluation techniques to sample ACM engagements has been an ongoing effort at NAVAIRTESTCEN, NAVWPNCEN, COMFITAEW-WINGPAC and CNA. The goal of the exploitation has been the development of tactically meaningful readiness measures through further mathematical development of the ACM models for application in aircraft test and evaluation and pilot training.

PURPOSE

2. This memorandum is intended as a supplement to references 1 and 4 to discuss the implementation of ACM analysis methods at several facilities, to present further developments, and to illustrate the use of the analytical methods via application to an example data set selected from a family of flight tests conducted on the Air Combat Maneuvering Range (ACMR). The data base and the numerical techniques described are also being used to guide further investigations into stochastic models useful for evaluating air combat maneuvering engagements.

1) R. A. Oberle, Air Combat Maneuver Conversion Model, Center for Naval Analyses Report No. CRC274, of Nov 1974.

2) Final Report, CNO Project P/V-2 (Battle Cry) (Task XII), Commander, Operational Test and Evaluation Force, Conduct an Operational Appraisal of the AV-8A Aircraft, of 24 Apr 1974 (Secret Report).

3) W. R. Simpson and M. T. Pilletere, Navy Evaluation of F-11A Inflight Thrust Control System, NAVAIRTESTCEN Report SA-C3R-76, Confidential Supplement to NAVAIRTESTCEN Report SA-75R-75, of 26 Jan 1976.

4) W. R. Simpson, Development of a Time-Variant Figure-of-Merit for Use in Analysis of Air Combat Maneuvering Engagements, NAVAIRTESTCEN Technical Memorandum TM-76-1SA, of 16 Jul 1976.

METHOD OF TESTS

3. Test methods for ACM evaluation are detailed in reference 4. This memorandum addresses the form of numerical techniques applied to quantitative ACM data.

ANALYSIS PARAMETERS

4. The primary ACM parameters to be used in this memorandum are given in table I. A complete listing of general technical terms is presented at the end of this report.

Table I

ACM Parameters

Parameter	Definition
Airplane Parameters	
Angle of Attack (AOA)	Angle between the free stream flow and the airplane reference line
Normal Acceleration (N_Z)	The load factor taken perpendicular to the flight path
Altitude (ALT)	Geometric altitude above ground level
Indicated Airspeed (IAS)	Airspeed measured by AIS uncorrected for position error
Specific Energy (E_S)	Sum of the weight specific kinetic and potential energies
Target Mach Number (MT)	Mach number of the target airplane
Interairplane Parameters	
Range (R)	Line of sight distance between the c.g. of two airplanes
Closing Velocity (VC)	Time rate of change of range
Antenna Train Angle (ATA)	The angle between the aircraft reference line forward of the c.g. and any sight line
Angle Off Tail (AOT)	The angle between the aircraft reference line aft of the c.g. and any sight line

Table I (Cont'd)

Parameter	Definition
Analysis Parameters	
Performance Index	A time variant figure-of-merit based on angular, range and energy penalty functions (detailed in reference 4)
Conversion Coefficient	An ACM state adaptation of the performance index (detailed in this memorandum)
ACM State	Maneuver conversion model state (detailed in reference 1)

ANALYSIS METHODS

5. The primary analysis methods employed in this report are the maneuver conversion model (detailed in reference 1) and the performance index model (reference 4). The maneuver conversion model characterizes an ACM engagement as a realization of a semi-Markov process with state conversion probabilities and time in state distributions. The performance index model is a continuous state continuous time stochastic process. A secondary analysis method, the conversion coefficient, combines the continuously varying measurement of the performance index and the state definitions of the maneuver conversion model to yield a third continuous time process. This third model, although suffering from discontinuities at state boundaries, is also being investigated for applicability to ACM evaluation. These models are used in combination because of their complimentary nature and the fact that the same conclusions follow from the three methodologies. Even though the maneuver conversion model includes a no-history Markov assumption and the performance index and conversion coefficient models assume a continuous time dependence, no conflict between results has yet been observed, nor is any expected. It is anticipated that for field application the analysts can select any of the methodologies for planning and evaluating a group of ACM flight tests. The methodology will primarily be chosen on the basis of off-line computational capability as well as the mathematical sophistication of the intended data usage.

ANALYSIS PROGRAMS

GENERAL

6. An analysis capability has been developed to define pertinent information and identify significant conclusions for air combat maneuvering engagements up to four fighter aircraft versus four target aircraft. Computer programs are available which calculate analysis data for specific aircraft pairs, fighter or bogie section analysis data for two-on-one engagements, and a stochastic analysis program for two-on-one engagements which is extendable to many versus many. The primary modes of analysis in these programs are the characterization of the semi-Markov parameters of the maneuver conversion model and a one dimensional evaluation of the stochastic process during the performance index model, together with stochastic data for the conversion coefficient and an expression of the expected paths for a statistical sample. The resulting numerical techniques are being used by the authors to support further theoretical development. For example, in reference 4, a feedback sequence leading to the development of a predictor model is discussed. Achievement of this predictor model requires a theoretical characterization of the underlying probability space for which the performance index and conversion coefficient are natural realizations. Identification of this underlying probabilistic structure is the goal of the ongoing investigations.

PAIRED ANALYSIS

7. The first step in the analysis is the computation of analysis parameters for fighter-to-adversary pairs in the engagement. The NAVAIRTESTCEN implementation of the paired analysis computer program is given in appendix A. Input is taken as the aircraft and interaircraft data of table I. These data are directly available from tests conducted at the ACMR in Yuma, Arizona, but can also be computed from use of radar data and onboard tape. Required inputs to the program are given in table II. These inputs are assumed to be at 1 second intervals from initialization. The beginning of the engagement can be taken analytically (such as at first visual contact) or mathematically (such as a fixed interaircraft range). Because of the inconsistency of results initialized at first visual contact, the latter is recommended.

Table II

Input Required for Paired Analysis Program

Input	Definition	Notes
TITLE	A 50-character identifier of the engagement	
ES1	Fighter aircraft specific energy	(1)
ES2	Target aircraft specific energy	
AOT	Fighter-to-target angle off tail	
ATA	Fighter-to-target antenna train angle	
R	Fighter-to-target interaircraft range	
RMAX1	Fighter offensive maximum range	(2)
RMAX2	Fighter defensive maximum range	
ROPT1	Fighter optimum missile launch range	
ROPT2	Target optimum missile launch range	
RO1	Target zero penalty range	
RO2	Fighter zero penalty range	
RG1	Fighter range at which guns tactics begin to dominate fight	
RG2	Target range at which guns tactics begin to dominate fight	
EDEV1	Fighter energy relevance term	
EDEV2	Target energy relevance term	
FG1	Fighter interenvelope gun penalty	
FG2	Target interenvelope gun penalty	
ATAOF	Antenna train angle for offensive state	(3)
AOTOF	Angle off tail for offensive state	
ATAWEP	Antenna train angle for weapons envelope	
AOTWEP	Angle off tail for weapons envelope	
R1WEP	Weapons envelope minimum range	
R2WEP	Weapons envelope maximum range	
RNUT	Range beyond which the fight is considered neutral for the maneuver conversion model	
NFILES	The number of data files to be input	
IPRINT	Print Option 1 for terminal output 5 for printer output	
IGRAF	Graph Option 1 for terminal output 5 for printer output	

NOTES: (1) As a function of time
(2) Defined in reference 4
(3) Defined in reference 1

8. The program computes and graphs the paired analysis data. An example data run is given in appendix B. Data output is defined in table III, and output data are placed on disk file for further use.

Table III

Output From Paired Analysis Program

Output	Definition	Notes
TIME	Assumed 1 second interval beginning at 1	
RANGE	Interaircraft range from table II	(1)
AOT	Angle off tail from table II	
ATA	Antenna Train Angle from table II	
NRG #1	Fighter aircraft ES1 from table II	
NRG #2	Target aircraft ES2 from table II	
DIR ANG	Normalized Directional Angle	(2)
NRG FN	Energy function for performance index calculation	
RNG FN	Range function for performance index calculation	
PERF INDEX	Performance Index	
STATE	ACM State	(3)

NOTES: (1) Output only on printer (print option 5). Not included in appendix B output.
(2) Defined in reference 4.
(3) Defined in reference 1.

SECTION ANALYSIS

9. The section coefficient data are computed by a second program as given in appendix C. The program was written for two versus one engagements and requires two output files generated by the previous program. These output files are for the two fighter-to-target pairs. The program computes the section performance index, section coordination, coordination consistency, the conversion coefficient, and the ACM state by the two-on-one state definitions of reference 1.

Section Performance Indices

10. The section performance indices are computed by the magnitude sum method (the vector sum method of reference 4). Section coordination and coordination consistency are computed as per reference 4.

Conversion Coefficient

11. The conversion coefficient was introduced to compensate for difficulties arising in the tactical interpretation of the section performance index. Specifically, as more aircraft are introduced, the section performance index becomes less responsive to tactical extremes because of mathematical "washout." That is, alternate signs in the performance index cancel to yield a numerically neutral fight which is often not representative of the tactical situation. For example, a precise interpretation of the "daisy chain" shown in figure 1 cannot be realized mathematically. The individual fighter-to-target performance indices cancel mathematically, yet tactically the fighter section is advantaged.

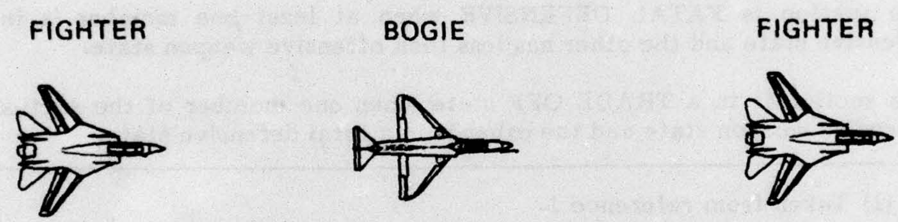

Figure 1
Air Combat "Daisy Chain" for Two-On-One Engagements

12. The situation as shown in figure 1 favors the fighter section if none of the aircraft are in a weapons envelope because of two very important reasons:

a. The forward fighter has a friendly observer looking over his rear quarter (the rear fighter).

b. In an attempt to close to the weapons envelope, the target aircraft in the middle will be flying a flight path which is in a large part determined by the first aircraft whose maneuvers can be made known to the rear aircraft. The situation will last only a short time with a smart pilot in the center aircraft and will quickly lead to "bogie switching," (a term applied to the situation) where the target (center) aircraft switches his offensive press to the other fighter.

13. The extension of the maneuver conversion model given in table IV covers this point adequately. (Rule 2 applies to the "daisy chain" of figure 1.)

Table IV[1]

Rules for State Evaluation of a Two-On-One Engagement

1.	The section is OFFENSIVE WEAPON when at least one member is in offensive weapon state and the other is higher than a fatal defensive state.
2.	The section is OFFENSIVE when at least one member has an offensive position and the other is higher than a fatal defensive state.
3.	The section is NEUTRAL when both members are in neutral state.
4.	The section is DEFENSIVE when at least one member is in defensive state and the other is either neutral or defensive.
5.	The section is FATAL DEFENSIVE when at least one member is in fatal defensive state and the other has less than offensive weapon state.
6.	The section is in a TRADE OFF state when one member of the section is in offensive weapon state and the other is in a fatal defensive state.

NOTE: (1) Taken from reference 1.

14. The conversion coefficient introduced in this memorandum is an attempt to modify the performance index to cover the "daisy chain" situation and increase responsiveness. It is computed along the lines of table IV as follows:

a. The conversion coefficient is equal to the section performance index when both of the paired performance indices are less than 30 in absolute value (corresponding to conditions 3 and 4 of table IV).

b. The conversion coefficient is equal to the section performance index when both paired performance indices have the same sign (corresponding in part to conditions, 2, 3, and 4 of table IV).

c. The conversion coefficient is equal to the section performance index when the paired performance indices are both greater than 75 in absolute value and opposite in sign (corresponding to condition 6 of table IV). These are flagged as a trade-off situation.

d. The conversion coefficient is not equal to the section performance index when the paired performance indices are opposite in sign and one is greater than 30 but less than 75. In this case, the conversion coefficient is computed as follows:

$$\text{CONCO} = PI_1^{\,2} \left(1 - \frac{|PI_2|}{75}\right) \tag{1}$$

where PI_1 is the positive value of the paired performance indices. This weights the positive (offensive factor) but degrades to a neutral value as a defensive fatal situation evolves (corresponding to condition 2 of table IV).

e. The conversion coefficient is not equal to the section performance index when the paired performance indices are opposite in sign with one greater than 75 in absolute value and both greater than 30 in absolute value. In this case, it is computed as follows:

$$\text{CONCO} = PI_1^{\,2} \left(1 - \frac{|PI_2|}{400}\right) \left(\frac{|PI_1|}{PI_1}\right) \tag{2}$$

where PI_1 is the paired performance index greater than 75 in absolute value and PI_2 is the other paired performance index. This weights the offensive weapons and defensive fatal states (corresponding to conditions 1 and 5 of table IV).

15. The conversion coefficient combines the best features of the maneuver conversion model with the performance index model but suffers in discontinuities due to equation changes at specified points. Care must be taken in further extensions of the conversion coefficient to include not only the case of the "daisy chain" (figure 2 shows a two versus two "daisy chain") but also other potential situations which cannot readily be described functionally such as the "floating diamond" in figure 3.

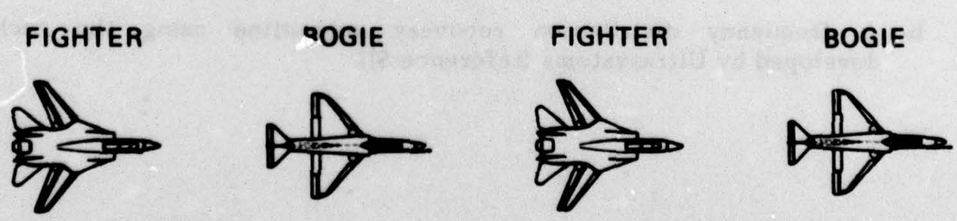

Figure 2
Air Combat "Daisy Chain" for Two-On-Two Engagements

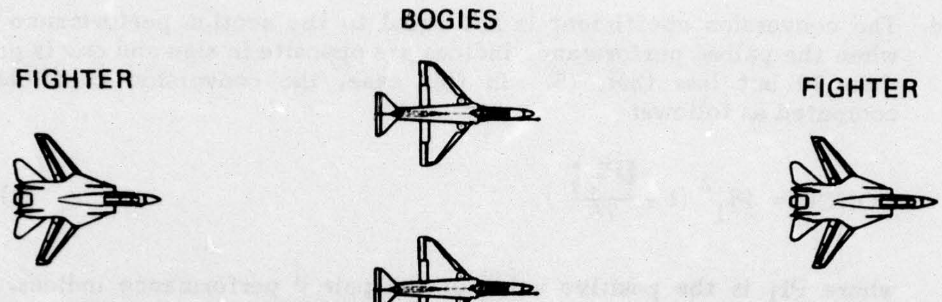

Figure 3
Air Combat "Floating Diamond" for Two-On-Two Engagements

Maneuver Conversion Model

16. The computation of the two-on-one ACM state is taken directly from table IV as obtained from reference 1.

Output of Section Analysis Program

17. An example output of the section analysis program is given in appendix D. The data are self-explanatory. These data are additionally output onto disk for use in the stochastic analysis program.

STOCHASTIC ANALYSIS

18. The stochastic analysis program takes the output data from both previous programs for a large sample of data. Because of the number of data points and calculations required, the program requires segmentation to fit most computers (the program given in appendix E takes in excess of 250K storage). Pertinent features of the program are:

a. A file of data management options which allows the user to selectively compute and output data as documented in appendix E.

b. A frequency distribution recovery subroutine using the techniques developed by Ultrasystems (reference 5).

5) Dr. R. Curry and Dr. R. Egbert, Investigation of Distribution Recovery Techniques, Operations Research and Economic Analysis Development Department, Ultrasystems, Incorporated, Newport Beach, California, 11 Feb 1974.

c. A moment generating routine calculating the classical moments of distributed functions with a given frequency distribution (reference 6).

d. An integration routine for integration of equally spaced functions using a combination of Simpson's rule and Newton's three-eighths rule (reference 7).

e. A general plot routine for use of the line printer in plotting developed at the NAVAIRTESTCEN.

19. The purposes of the stochastic analysis program are to:

a. Compute the frequency distributions of the continuous variables in time for section data and paired data.

b. Compute the first 4 moments of these frequency distributions.

c. Compute the maneuver conversion/conversion probability matrix for aircraft sections and pairs.

d. Compute the time in state frequency distributions for the maneuver conversion model.

e. Compute the first 4 moments of these frequency distributions.

Stochastic Analysis Program Output

20. Full output of the stochastic analysis program is too voluminous to present here. Selected output for the test run and significant analysis information is, however, included for documentation. The test run, while representing actual engagement data, is for purposes of illustrating analysis methodology only. Separate reports are being written covering test data analysis and conclusions.

Continuous Variable Frequency Distributions and Moment Data

21. Frequency data output at 5 second intervals and for selected values of the performance index are shown in table V for a sample data set. The conclusions to be drawn from the data set are a function of the frequency value assumed to be significant. For example, the attainment of an optimal position (either best or worst) will come much less frequently than the neutral position. In table V, if a significance level of .001 is used, it can be seen that an optimal position will be attainable for the fighter section 20-30 seconds into the fight (a performance index of +100). This value does not occur until 80-90 seconds for the target (a performance index value of -100). This would indicate an early advantage to the fighter section and a recommended action to press and exploit the early advantage.

6) H. G. Kendall, The Advanced Theory of Statistics, Vol. I. Hafner Publishing Company, New York, 1958.

7) System 360 Scientific Subroutine Package (360A-CM-03X) Version II Programmers Manual, International Business Machines Report H20-0205-2, White Plains, N.Y., 1967.

Table V

Performance Index Distribution for Two-On-One Example Data Set

Time	Frequency of Occurrence of Specific Performance Indices									
	-100	-98	-80	-78	0	2	80	82	98	100
(sec)	Frequency Index									
1	0.00000	0.00000	0.00000	0.00000	0.03268	0.03643	0.00000	0.00000	0.00000	0.00000
6	0.00000	0.00000	0.00001	0.00001	0.01432	0.01553	0.00004	0.00002	0.00000	0.00000
11	0.00010	0.00012	0.00044	0.00050	0.00944	0.00976	0.00157	0.00135	0.00030	0.00025
16	0.00025	0.00029	0.00092	0.00103	0.00793	0.00814	0.00273	0.00246	0.00092	0.00080
21	0.00061	0.00068	0.00149	0.00160	0.00805	0.00819	0.00303	0.00280	0.00132	0.00119
26	0.00058	0.00064	0.00135	0.00146	0.00806	0.00822	0.00323	0.00299	0.00148	0.00134
31	0.00016	0.00019	0.00076	0.00087	0.00949	0.00953	0.00232	0.00212	0.00090	0.00080
36	0.00032	0.00036	0.00100	0.00111	0.00955	0.00963	0.00228	0.00209	0.00093	0.00082
41	0.00010	0.00012	0.00040	0.00044	0.01115	0.01133	0.00177	0.00155	0.00043	0.00035
46	0.00011	0.00013	0.00047	0.00053	0.01055	0.01073	0.00173	0.00153	0.00047	0.00039
51	0.00000	0.00000	0.00011	0.00015	0.01245	0.01263	0.00019	0.00014	0.00001	0.00001
56	0.00000	0.00000	0.00010	0.00014	0.01238	0.01237	0.00028	0.00021	0.00002	0.00001
61	0.00003	0.00004	0.00030	0.00036	0.01229	0.01228	0.00078	0.00066	0.00013	0.00010
66	0.00009	0.00011	0.00060	0.00070	0.01064	0.01068	0.00132	0.00116	0.00034	0.00029
71	0.00043	0.00049	0.00129	0.00142	0.00858	0.00867	0.00262	0.00241	0.00109	0.00097
76	0.00054	0.00061	0.00155	0.00169	0.00809	0.00814	0.00287	0.00266	0.00132	0.00120
81	0.00057	0.00065	0.00178	0.00195	0.00799	0.00808	0.00220	0.00199	0.00080	0.00070
86	0.00150	0.00161	0.00287	0.00302	0.00696	0.00697	0.00328	0.00311	0.00187	0.00173
91	0.00173	0.00185	0.00308	0.00323	0.00734	0.00734	0.00282	0.00268	0.00169	0.00159
96	0.00093	0.00104	0.00254	0.00276	0.00850	0.00839	0.00158	0.00147	0.00074	0.00068
101	0.00125	0.00138	0.00300	0.00323	0.00805	0.00794	0.00166	0.00154	0.00078	0.00071
106	0.00057	0.00066	0.00215	0.00240	0.00835	0.00820	0.00126	0.00113	0.00041	0.00035
111	0.00067	0.00077	0.00212	0.00232	0.00791	0.00793	0.00173	0.00155	0.00054	0.00047
116	0.00124	0.00137	0.00288	0.00309	0.00770	0.00765	0.00200	0.00185	0.00089	0.00081
121	0.00057	0.00067	0.00243	0.00272	0.00820	0.00809	0.00081	0.00071	0.00022	0.00018
126	0.00089	0.00100	0.00255	0.00278	0.00810	0.00803	0.00153	0.00139	0.00056	0.00049
131	0.00100	0.00112	0.00253	0.00273	0.00788	0.00785	0.00206	0.00190	0.00089	0.00080
136	0.00103	0.00114	0.00247	0.00265	0.00798	0.00796	0.00224	0.00209	0.00105	0.00096
141	0.00086	0.00096	0.00229	0.00249	0.00806	0.00799	0.00229	0.00214	0.00115	0.00106
146	0.00130	0.00142	0.00285	0.00305	0.00768	0.00762	0.00236	0.00222	0.00124	0.00114
151	0.00066	0.00076	0.00216	0.00239	0.00845	0.00827	0.00189	0.00177	0.00093	0.00085
156	0.00121	0.00134	0.00292	0.00314	0.00810	0.00796	0.00197	0.00188	0.00121	0.00114
161	0.00129	0.00142	0.00306	0.00328	0.00804	0.00790	0.00172	0.00162	0.00088	0.00080
166	0.00185	0.00201	0.00374	0.00396	0.00699	0.00686	0.00237	0.00226	0.00145	0.00136
171	0.00276	0.00291	0.00442	0.00459	0.00674	0.00665	0.00243	0.00234	0.00169	0.00162
176	0.00256	0.00273	0.00448	0.00469	0.00698	0.00685	0.00192	0.00184	0.00130	0.00124
181	0.00343	0.00357	0.00487	0.00502	0.00660	0.00651	0.00233	0.00225	0.00167	0.00161
186	0.00089	0.00102	0.00284	0.00313	0.00839	0.00812	0.00073	0.00065	0.00022	0.00019

22. For the fringe of a weapons envelope (as shown in table V) at a value of +80 for the fighter or -80 for the target, a significance level of .003 may be chosen due to the higher incidence of occurrence. These values again occur at 20-30 seconds for the fighter section (+80 performance index) and much later, 80-90 seconds for the target (-80 performance index) with the same conclusions. Further, the data indicate a loss of this advantage in the later stages of the fight due to the higher frequency of occurrence of performance indices in the negative range after 90 seconds, suggesting it may be desirable for the fighters to stay engaged for only short periods (say up to 60 seconds). The defensive disengagement for the fighter section between 60 and 90 seconds is the tactical defense to the tide of battle shifting to the bogie. The neutral values (values of performance index near 0) are included for reference.

23. Table VI shows the statistical summary data for the data of table V. The variation of the mean as a function of time points again to an early advantage to the fighter section and loss of that advantage at around 90 seconds into the fight. The variance shows that events in the latter half of the engagement are more random in nature (larger relative values of variance). That is, events are less in control of either the fighter section or the target section, but not a significant difference. The value of the mean is indicative of the relative worth of the two sections and the engagements show to be predominantly neutral with a slight advantage to the fighter section initially and a slight advantage to the target section later in time. The overall conclusion is that the sections are fairly equally matched. The third and fourth moments were computed for later analysis and model building.

24. Figure 4 shows the output of the frequency of occurrence plot as a function of performance index for the start of the set of engagements. Figure 4(a) shows a tightly distributed data set in the region of -16 to +20 indicating a neutral start condition. One or more engagements are seen to start with the fighter section at a disadvantage as shown in the secondary peak between -30 and -16, and these engagements should probably be deleted from the engagement set for the neutral start analysis.

Table VI

Summary Statistics for Section Performance Index Distribution

Time (sec)	Number of Points	Mean Performance Index	Variance of Performance Index	Third Moment of Performance Index About Mean	Fourth Moment of Performance Index About Mean
1	33	6.34	114.37	-636.67	56159.57
6	33	12.80	462.40	-4176.03	757210.59
11	33	14.57	1151.75	-12832.23	3800686.85
16	33	13.90	1570.17	-19020.63	6318563.84
21	33	10.42	1811.55	-17839.51	8065442.44
26	33	12.29	1782.15	-19620.96	7975665.77
31	33	8.27	1491.78	-1178.67	5558583.45
36	33	8.14	1527.16	-5578.23	6023055.01
41	33	13.02	1120.23	-4447.80	3593418.53
46	33	11.47	1198.91	-5504.27	3974260.30
51	32	5.99	807.96	-4006.78	1734312.40
56	32	3.55	847.04	380.94	1840745.63
61	32	4.27	1000.48	1595.19	2757920.97
66	32	4.97	1249.15	-201.43	4090099.35
71	30	8.30	1702.58	-9678.55	7107357.44
76	30	7.00	1850.01	-7680.61	8024471.00
81	30	4.25	1800.18	-9594.28	7555697.28
86	30	2.31	2300.12	-5018.21	11336444.27
91	29	-0.77	2242.77	1069.86	11057383.18
96	28	-7.02	1766.26	12959.65	7677819.65
101	27	-8.54	1871.21	15561.02	8432997.65
106	27	-8.12	1624.86	14356.95	6497451.97
111	27	-0.96	1797.02	-1663.24	7357124.42
116	27	-4.89	1983.82	8765.20	8980127.66
121	27	-11.43	1540.44	12607.21	5774302.76
126	25	-6.31	1789.32	9495.46	7541745.63
131	24	-2.79	1934.10	5310.66	8574531.13
136	24	-1.51	1957.46	3766.21	8824056.90
141	21	-1.93	1927.95	9173.04	8660194.07
146	19	-3.53	2064.53	9781.27	9692787.76
151	19	-6.13	1768.54	19825.28	7818620.14
156	18	-7.86	1930.58	21118.76	9156490.34
161	18	-9.46	1879.12	19982.05	8677585.29
166	16	-9.20	2209.73	27797.15	11175677.66
171	14	-10.19	2369.51	27960.52	12478168.37
176	14	-13.59	2179.04	31991.96	11230738.18
181	12	-11.99	2422.24	30528.05	12983093.75
186	10	-16.13	1456.25	18236.56	5761935.46

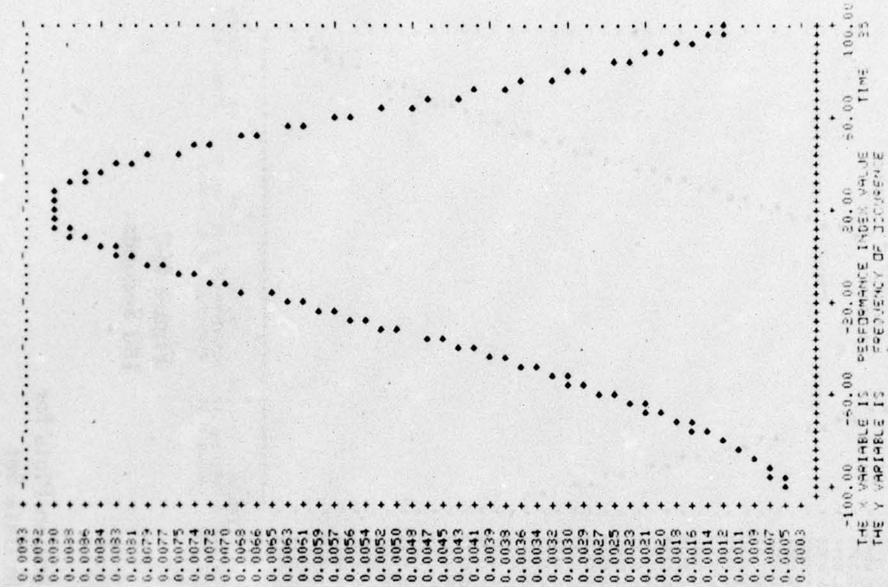

Figure 4(b)
25 Seconds

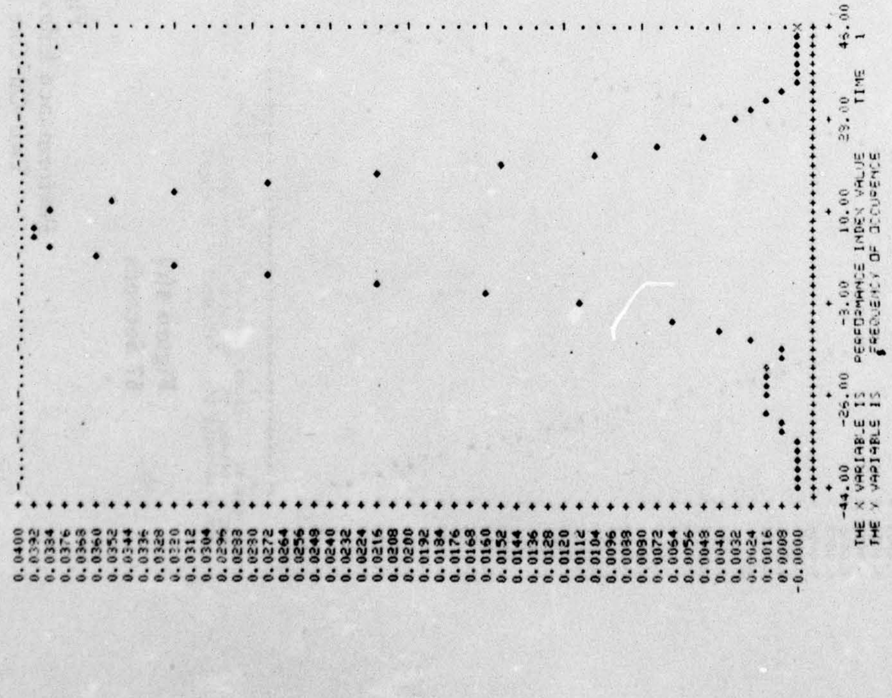

Figure 4(a)
Start of Engagement

Figure 4
Performance Index Distribution Plots for Two-On-One Example Data Set

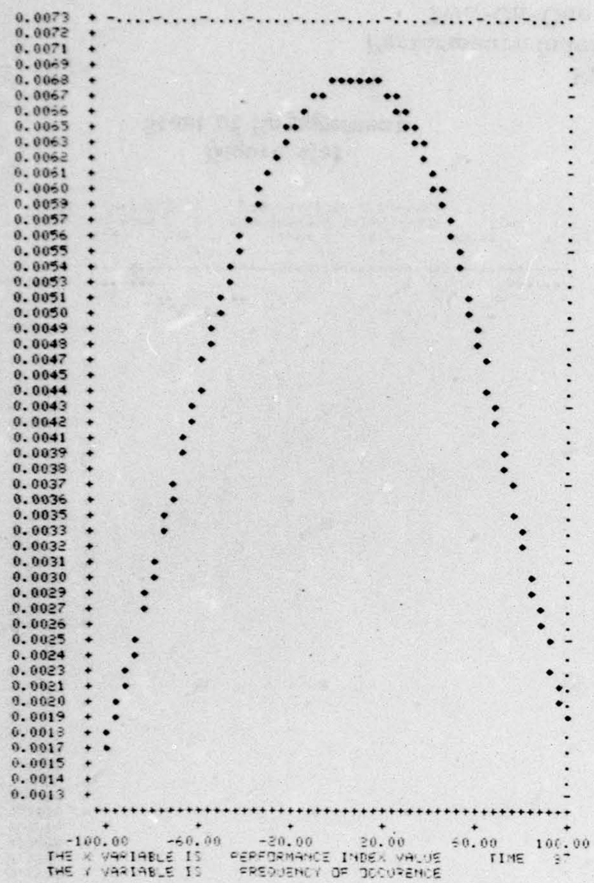

Figure 4(c)
87 Seconds

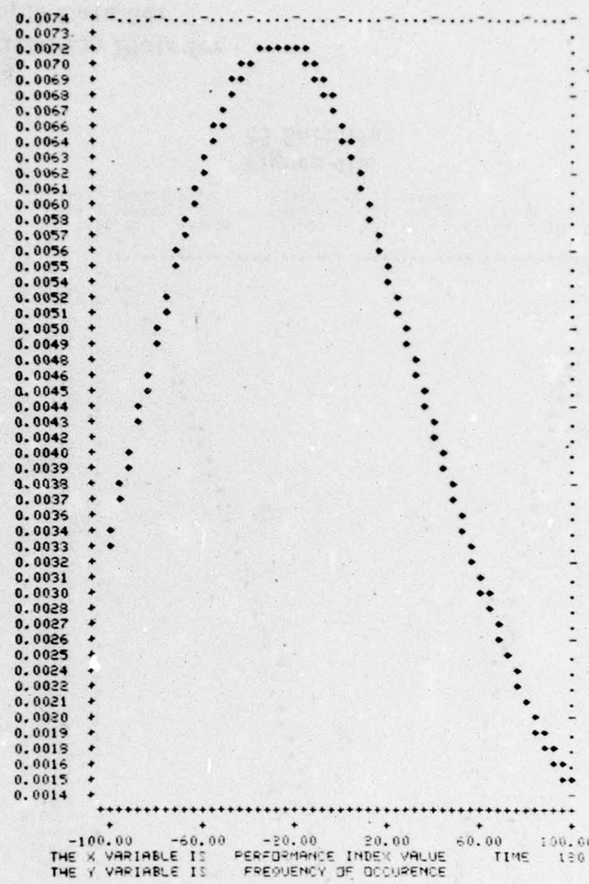

Figure 4(d)
180 Seconds

Figure 4
Performance Index Distribution Plots for Two-On-One Example Data Set

25. Figure 4(b) shows the output of the frequency of occurrence plot as a function of performance index for a time 25 seconds into the engagements. As discussed in paragraphs 21 and 22, it can be seen that for a significance level of 0.003, the distribution of performance indices lies between -54 and +82 which contains the fringe weapon envelope case for the fighter section (+80), but not the target (-80), indicating a decided advantage for the fighter section in this time frame. Thus, the neutral starts have shifted to a fighter section advantage during the initial engagement period.

26. Figures 4(c) and 4(d) show the reversal of this trend later in the engagement. In figure 4(c), the frequency distribution at 87 seconds into the engagements shows that both the fighter section and the target section have weapon opportunities available. Figure 4(d), taken for 180 seconds into the engagements, shows a very skewed distribution which includes weapon opportunities for the target aircraft but none for the fighter section. This reflects the breakdown of the fighter section integrity as engagement time accumulates and the resulting dominance by the bogie. At this point, the fighters are essentially uncoordinated and the more maneuverable bogie is selectively engaging the most vulnerable fighter of the section.

27. Engagement dominance can be taken from the cumulative probability of occurrence of performance indices at various times during the engagements as shown in figure 5 for the times corresponding to figure 4. Mathematically, the fighter section will dominate if a positive value of performance index has a cumulative probability of greater than 50%. Practically, however, the split should be greater than 51/49 or more like 70/30. As shown in the figures, and taking the split in the value of cumulative probability at zero performance index, no tendency to dominate is present in either the fighter section or the target aircraft over the entire engagement time. There is, however, a mathematical tendency for the fighter section to dominate early in the fight and to lose this advantage to the target aircraft later in the fight. This is consistent with the trend isolated by the time history of expected values discussed in paragraph 23. While no combatant controlled the entire engagement, the initial engagement dominance by the fighter section is a decided advantage since the fighter section will incur the majority of early shot opportunities.

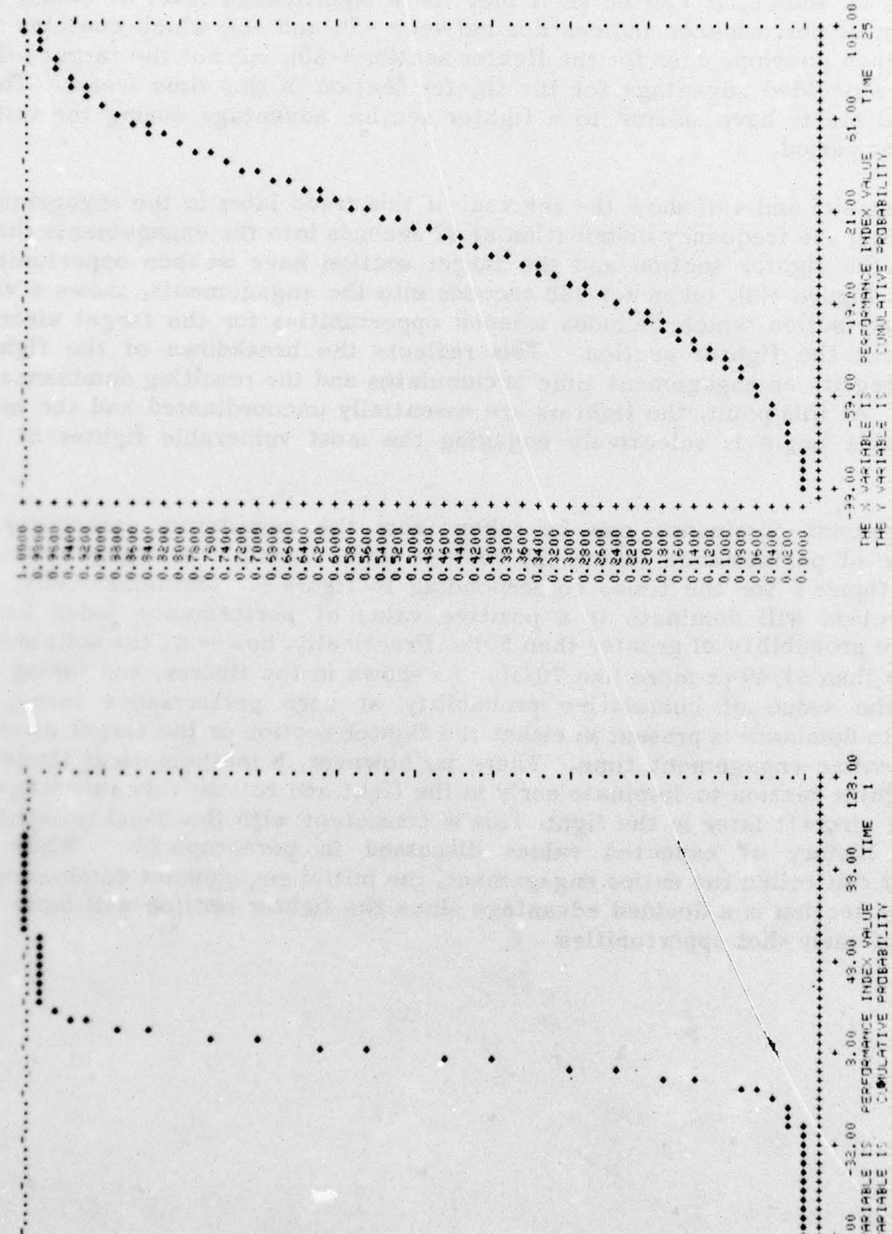

Figure 5(a)
Start of Engagement

Figure 5(b)
25 Seconds

Figure 5
Cumulative Probability Plots for Performance Indices
of Two-On-One Example Data Set

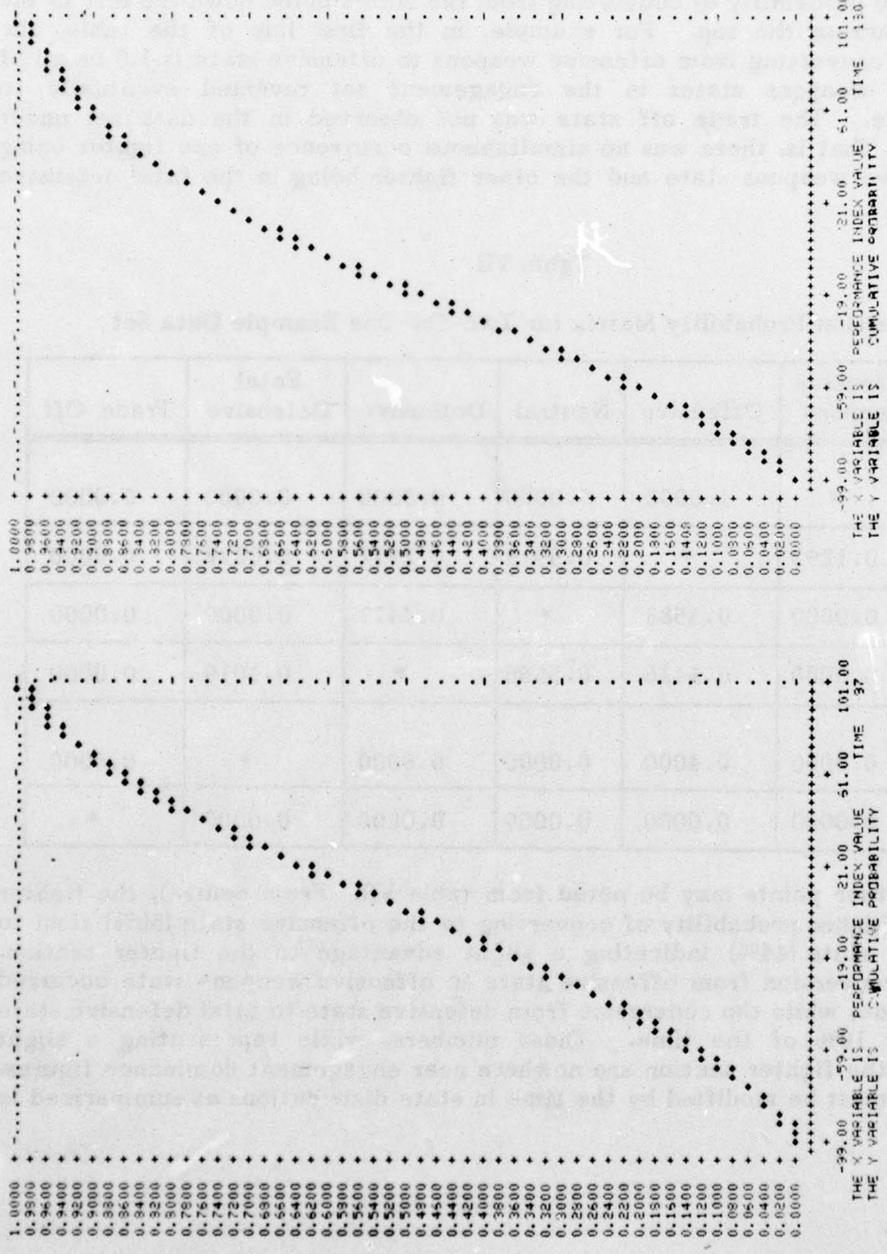

Figure 5(c)
87 Seconds

Figure 5(d)
180 Seconds

Figure 5
Cumulative Probability Plots for Performance Indices
of Two-On-One Example Data Set

<u>Maneuver Conversion/Conversion Probability Matrix</u>

28. Table VII shows the program output of the conversion probability matrix for the sample data set as computed by the methods described in reference 1. The table shows the probability of converting from the states listed down the left to the states listed across the top. For example, in the first line of the table, the probability of converting from offensive weapons to offensive state is 1.0 or all of the offensive weapons states in the engagement set reverted eventually to offensive state. The trade off state was not observed in the data set under investigation. That is, there was no simultaneous occurrence of one fighter being in the offensive weapons state and the other fighter being in the fatal defensive state.

Table VII

Conversion Probability Matrix for Two-On-One Example Data Set

Section State	Offensive Weapons	Offensive	Neutral	Defensive	Fatal Defensive	Trade Off
Offensive Weapons	*	1.0000	0.0000	0.0000	0.0000	0.0000
Offensive	0.1293	*	0.5918	0.2517	0.0272	0.0000
Neutral	0.0000	0.5583	*	0.4417	0.0000	0.0000
Defensive	0.0000	0.3426	0.5556	*	0.1019	0.0000
Fatal Defensive	0.0000	0.4000	0.0000	0.6000	*	0.0000
Trade Off	0.0000	0.0000	0.0000	0.0000	0.0000	*

29. Several other points may be noted from table VII. From neutral, the fighter section had a higher probability of converting to the offensive state (56%) than to the defensive state (44%) indicating a slight advantage to the fighter section. Further, the conversion from offensive state to offensive weapons state occurred 13% of the time, while the conversion from defensive state to fatal defensive state occurred only 10% of the time. These numbers, while representing a slight advantage to the fighter section are nowhere near engagement dominance figures. Further, they must be modified by the time in state distributions as summarized in table VIII.

Table VIII

Time in State Summary for Two-On-One Example Data Set

Section State	Number of Points	Mean Time in State (sec)	Variance of Mean Time in State (sec^2)	Third Moment about Mean Time in State (sec^3)	Fourth Moment about Mean Time in State (sec^4)
Offensive Weapons	18	2.93	4.39	9.74	68.59
Offensive	142	14.52	141.52	2329.60	96707.36
Neutral	153	18.13	206.64	3876.30	197143.09
Defensive	97	15.30	136.32	1862.18	77235.03
Fatal Defensive	16	2.56	5.08	14.96	96.76
Trade Off	0	0.00	0.00	0.00	0.00

30. As shown in table VIII, the mean time spent in the offensive state is somewhat less than the mean time spent in the defensive state for roughly the same variance (same degree of consistency), thus offsetting the partial advantage to the fighter section. The nonparametric frequency function fits for time in offensive, neutral, and defensive states displayed the log normal characteristic referred to in reference 2. Figure 6(a) shows the time in state distribution for the offensive state.

31. Time in state distributions for the offensive weapons and defensive fatal states are multimodal and means do not compare directly. Figure 6(b), the time in state distribution of the offensive weapons state for the fighter section, is characterized as a bimodal distribution which approximates the log normal form. Figure 6(c), the time in state distribution of the fatal defensive state for the fighter section, is characterized by a trimodal distribution which approximates the log normal form. The primary difference in the two states is probably characterized by the pilot tactics employed in two-on-one engagements. The first peak in figure 6(b) probably represents a transient or "flash through" computation in the neighborhood of one second, while the second peak (at 8.5 to 9 seconds) represents the tracking solution. The fatal defensive state (figure 6(c)) shows both these peaks, together with an intermediate peak which is probably due to 'bogie switching' as discussed in paragraph 12. The target aircraft, being threatened, in some instances would not complete the tracking solution, but hold the state for some finite time (around 5 seconds), fire a missile, and then switch. No such pressures to switch states are incumbent upon the fighter section in a two-on-one engagement. This intermediate short duration peak could be termed the 'survival sting' peak. This logic would lead to the supposition that a trimodal distribution for offensive weapons and defensive fatal states would be present in all engagements with multiple bogies and multiple fighters. The above observations are based upon a small data base and must be verified by further data samples.

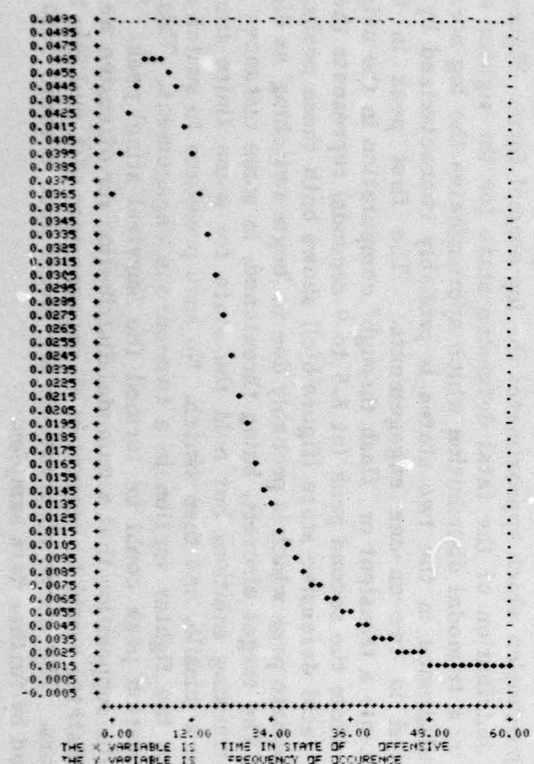

Figure 6(a)
Offensive State

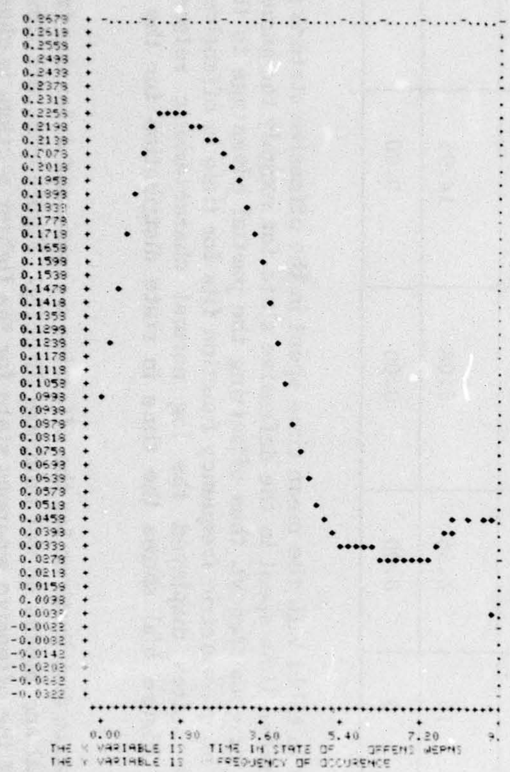

Figure 6(b)
Offensive Weapons State

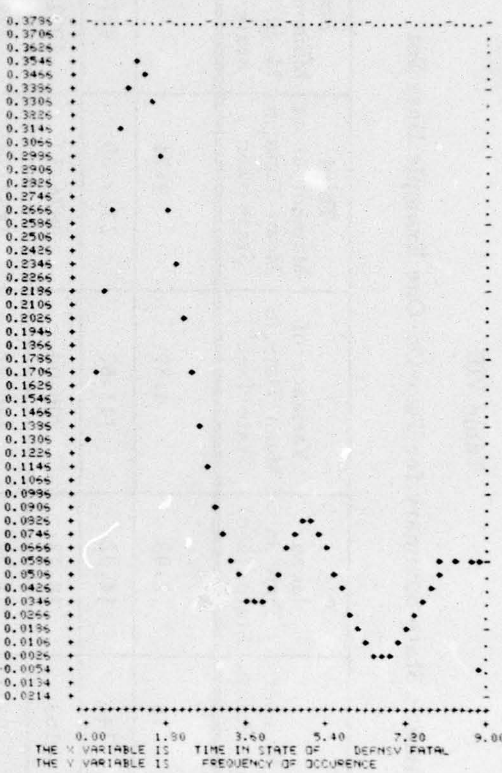

Figure 6(c)
Fatal Defensive State

Figure 6
Time in State Distributions for Two-On-One Example Data Set

32. The above discussion exhausts the conclusions that can be drawn directly from the estimated values of the maneuver conversion parameters. Further analysis, for example, the complete characterization of the underlying probability space and the estimation of the expected trade off ratio (the ratio of the probability of a win to the probability of a loss), requires the methodology described in reference 8. Since the techniques are adequately described in reference 8, they will not be repeated here.

33. At this point in the analysis, the semi-Markov process of the maneuver conversion model is defined, and when integrated with the weapon employment parameters, the full range of ACM measures of effectiveness including exchange ratios, survivability and dominance indices, etc., can be computed. These terms are treated in detail in references 1 and 8. The stochastic process of the performance index is only partially defined and is still in the developmental phase.

MODEL VALIDATION

34. The question of model validity may be addressed at two levels. The first level is consistency of conclusions drawn from the differing analytic techniques. The above discussions demonstrate this consistency for the data set under consideration. The authors believe that the two models are equally right or equally wrong. Thus, validation is reduced to determining if either model characterizes ACM correctly. An indication of this validity has already been obtained by noting the consistency of the common conclusion set with the intuitive evaluation of the participating aircrews. A formal mathematical validation may be obtained by comparing the tactical measures (listed in reference 1) as estimated from the computer solution of the semi-Markov process and as estimated directly from the data sample. Although this has not been done for this data sample, a valid comparison has been described in reference 8.

8) R. A. Oberle and W. R. Nunn, Evaluation of Air Combat Maneuvering Engagements, CNA Study No. 77-3, (to be published).

CURRENT RESEARCH

35. The above discussion summarizes some of the early research into the evaluation of test range ACM engagements. Work is continuing toward the development of a completely mathematical characterization of such engagements. Specifically, the investigations are directed toward a complete characterization of the underlying probability structure for which the performance index and conversion coefficient are natural realizations. The numerical techniques discussed above not only provide tactically significant data interpretation techniques but also serve as the initial technical tools to support the ongoing research. Further numerical techniques which are expected to be useful for data interpretation include a full nonparametric covariance and increment analysis along with selected distribution fitting analyses. The current research emphasis centers around a characterization of the performance index as a solution of a stochastic differential equation. It is expected that such a characterization will identify a few stochastic parameters that will serve to replace the mass of numerical calculations currently necessary as well as identify the theoretical connection between the maneuver conversion and the performance index models.

REFERENCES

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2. Final Report, CNO Project P/V-2 (Battle Cry) (Task XII), Commander, Operational Test and Evaluation Force, Conduct an Operational Appraisal of the AV-8A Aircraft, of 24 Apr 1974 (Secret Report).

3. W. R. Simpson and M. T. Pilletere, Navy Evaluation of F-11A Inflight Thrust Control System, NAVAIRTESTCEN Report SA-C3R-76, Confidential Supplement to NAVAIRTESTCEN Report SA-75R-75, of 26 Jan 1976.

4. W. R. Simpson, Development of a Time-Variant Figure-of-Merit for Use in Analysis of Air Combat Maneuvering Engagements, NAVAIRTESTCEN Technical Memorandum TM-76-1SA, of 16 Jul 1976.

5. Dr. R. Curry and Dr. R. Egbert, Investigation of Distribution Recovery Techniques, Operations Research and Economic Analysis Development Department, Ultrasystems, Incorporated, Newport Beach, California, of 11 Feb 1974.

6. H. G. Kendall, The Advanced Theory of Statistics, Vol. I, Hafner Publishing Company, New York, 1958.

7. Systems 360 Scientific Subroutine Package (360A-CM-03X) Version II Programmers Manual, International Business Machines Report H20-0205-2, White Plains, N.Y., 1967.

8. R. A. Oberle and W. R. Nunn, Evaluation of Air Combat Maneuvering Engagements, CNA Study No. 77-3, (to be published).

PAIRED ANALYSIS PROGRAM

```
L PFINDX_

FILE:PFINDX -03/13/76 10:22 AM.
100 $ERRMES
200 FILE  5=RANDY,UNIT=PRINTER BACKUP DISK
300 FILE  4=REF,UNIT=DISK
400 FILE  2=ACM,UNIT=DISK
500 FILE  3=CNST,UNIT=DISK
600 FILE  1=TRMNL,UNIT=REMOTE
700  INTEGER X
800  REAL K
900  DIMENSION TITLE(50)
910  DIMENSION ISTAT(500)
1000  DIMENSION STATE(500)
1100  DIMENSION BE(500),AA(500)
1200  DATA BLANK,DOT,STAR,XXX/" ",".","*","X"/
1300  DATA PLUS/"+"/
1400  DATA OFWEP,OFF,DEF,NUT,DEFAT/"W","O","D","N","F"/
1410 C-
1420 C- DATA FOR ACM STATE CALCULATION W=OFFENSIVE WEAPON STATE
1430 C-                                O=OFFENSIVE STATE
1440 C-                                N=NEUTRAL STATE
1450 C-                                D=DEFENSIVE STATE
1460 C-                                F=DEFENSIVE FATAL STATE
1470 C-
1480 C-
1500  DIMENSION R(500),K(500),FRNG(500),DA(500),PI(500)
1600  DIMENSION ES1 (500)
1700  DIMENSION ES2 (500)
1800  DIMENSION AOT (500)
1900  DIMENSION ATA (500)
1950  IFIL=1
1960  PRINT 433
1970  433 FORMAT(5X,"HOW MANY FILES AM I LOOKING AT")
1980  READ(1,/) NFILES
2000  KOUNT=1
2100  READ(3,/) RMAX1,RMAX2,ROPT1,ROPT2,R01,R02,RG1,RG2,EDEV1,EDEV2,
2110 C-
2115 -FG1,FG2,ATAOF,AOTOF,R1WEP,R2WEP,RNUT,ATAWEP,AOTWEP
2120 C- SEE TEXT FOR EXPLANATION OF THESE NUMBERS
2130 C-
2800  PRINT 434
2900  434 FORMAT(5X,"WHERE DO YOU WANT DATA OUT, 1=HERE, 5=PRINTER",
3000 -"OTHERS=NONE")
3100  READ(1,/) IPRINT
3200  PRINT 435
3300  435 FORMAT(5X,"WHERE DO YOU WANT A GRAPH, 1=HERE, 5=PRINTER",
3400 -"OTHERS=NONE")
3500  READ(1,/) IGRAF
3510  86 CONTINUE
3512  KOUNT=1
3515  READ(2,/) N,(R(I),I=1,N),(ES1(I),I=1,N),(ES2(I),I=1,N),
3520 -(AOT(I),I=1,N),(ATA(I),I=1,N)
3530  READ(2,111) (TITLE(I),I=1,50)
3540  111 FORMAT(50A1)
3550  191 CONTINUE
3560  WRITE(1,111) (TITLE(I),I=1,50)
3600  IF(IPRINT.EQ.1.OR.IPRINT.EQ.5) GO TO 987
3700  GO TO 100
```

```
997 CONTINUE
WRITE(IPRINT,1003) (TITLE(I),I=1,50)
1003 FORMAT(1H1,10X,50A1)
WRITE(IPRINT,444) RMAX1,RMAX2,ROPT1,ROPT2,R01,R02,RG1,RG2,
-EDEV1,EDEV2,FG1,FG2,ATAOF,AOTOF,ATAWEP,AOTWEP,R2WEP,R1WEP,RNUT
444 FORMAT(10X,"INPUT CONSTANTS FOR THIS RUN",/
-10X," FIGHTER OFFENSIVE  MAX RANGE",F10.1," TARGET =",F10.1,/
-10X," FIGHTER OPT MISSILE RANGE   ",F10.1," TARGET =",F10.1,/
-10X," FIGHTER MINIMUM RANGE (GUN) ",F10.1," TARGET =",F10.1,/
-10X," FIGHTER GUN ENVELOPE RMAX   ",F10.1," TARGET =",F10.1,/
-10X," FIGHTER ENERGY RELEVENCE    ",F10.4," TARGET =",F10.4,/
-10X," FIGHTER INTER-ENVELOPE PENAL",F10.4," TARGET =",F10.4,/
-10X,"OFFENSIVE ATA=",F10.1," AOT=",F10.1,/
-10X,"OFF WEP ATA=",F10.1,"AOT=",F10.1,/
-10X,"OFF WEP RMAX=",F10.1,"RMIN=",F10.1,/
-10X,"FIGHT NUETRAL BEYOND",F10.1," RANGE")
IF(IPRINT.EQ.1) WRITE (1,30)
IF(IPRINT.EQ.5) WRITE(5,301)
301 FORMAT(5X,"TIME  RANGE  AOT  ATA  NRG#1  NRG#2  DIR ANG",
-"  NRG FN  RNG FN  PERF INDEX   STATE")
30 FORMAT(5X,"TIME        DIR ANG   NRG FN      RNG FN",4X,
-"PERF INDEX","   STATE")
C-
C- COMPUTE ACM STATE
C-
100 DO 10 I=1,N
STATE(I)=NUT
IF(ATA(I).LE.ATAOF.AND.AOT(I).LE.AOTOF) STATE(I)=OFF
IF(ATA(I).LE.ATAWEP.AND.AOT(I).LE.AOTWEP.AND.R(I).GE.R1WEP.AND.
-R(I).LE.R2WEP) STATE(I)=OFWEP
IF(ATA(I).GE.(180.-AOTOF).AND.AOT(I).GE.(180.-ATAOF)) STATE(I)=DEF
IF(ATA(I).GE.(180.-AOTWEP).AND.AOT(I).GE.(180.-ATAWEP).AND.
-R(I).GE.R1WEP.AND.R(I).LE.R2WEP) STATE(I)=DEFAT
IF(R(I).GT.RNUT) STATE(I)=NUT
C-
C- COMPUTE NORMALIZED DIRECTIONAL ANGLE
C-
DA(I)=100.*((180.-(AOT(I)+ATA(I)))/180.).
IF(DA(I)+0) 15,25,25
C-
C- BRANCH ON DIRECTIONAL ANGLE  PLUS FOR OFFENSIVE FIGHTER
C-                             MINUS FOR DEFENSIVE FIGHTER
C-
15 CONTINUE
RMAX=RMAX2
ROPT=ROPT2
R0=R02
RG=RG2
EDEV=EDEV2
FG=FG2
GO TO 45
25 RMAX=RMAX1
ROPT=ROPT1
R0=R01
RG=RG1
EDEV=EDEV1
FG=FG1
45 IF(RG.EQ.ROPT.OR.RG.EQ.R0.OR.FG.EQ.0.) GO TO 35
```

```
C-
C-   BEGIN COMPUTATION OF PERFORMANCE INDEX
C-
 FSTR=FG/((RG/RMAX)*((RG-ROPT)/RMAX*(RG-R0)/RMAX)**2)
 GO TO 55
 35 FSTR=0.
 55 A=R(I)
 B=(A-ROPT)/RMAX
 C=(A-R0)/RMAX
 D=EXP(-8.*((A-RG)/ROPT)**2)
 E=FSTR*A/RMAX*(B*C*D)**2
 FRNG(I)=E+1./(1.+500.*EXP(-12.*B))
 ESD=ES1(I)-ES2(I)
 ESB=(ES1(I)+ES2(I))/2.
 DES=ESD/ESB
 GEE=(2.*R(I)-RMAX-ROPT)/(RMAX-ROPT)
 EFF=EDEV*EXP(-4.*GEE**2)
 ECH=1./(1.+EDEV*EXP(-6.91*R(I)/R0))
 K(I)=1.+(ECH+EFF-1.)*DES
 IF(DA(I)+0)17,18,18
 17 K(I)=1./K(I)
 18 CONTINUE
 PI(I)=DA(I)*K(I)*(1.-FRNG(I))
 IF(IPRINT.EQ.1.OR.IPRINT.EQ.5) GO TO 986
 GO TO 10
 986 CONTINUE
 IF(KOUNT.EQ.45) WRITE(IPRINT,1003) (TITLE(KK),KK=1,50)
 IF(KOUNT.EQ.45.AND.IPRINT.EQ.5) WRITE(5,301)
 IF(KOUNT.EQ.45.AND.IPRINT.EQ.1) WRITE(1,30)
 IF(KOUNT.EQ.45) KOUNT=0
 KOUNT=KOUNT+1
 IF(IPRINT.EQ.5) WRITE(5,278) I,R(I),AOT(I),ATA(I),ES1(I),ES2(I),
-DA(I),K(I),FRNG(I),PI(I),STATE(I)
 278 FORMAT(6X,I3,2X,I5,2(2X,I3),2(2X,I5),2X,F6.2,2X,F7.4,
-F7.4,2X,F10.2,5X,A1)
 IF(IPRINT.EQ.1) WRITE(1,20) I,DA(I),K(I),FRNG(I),PI(I),STATE(I)
 20 FORMAT(5X,I4,6X,F7.2,3X,F6.4,4X,F6.4,4X,F10.2,5X,A1)
 10 CONTINUE
 KOUNT=1
 IF(IGRAF.EQ.1.OR.IGRAF.EQ.5) GO TO 985
 GO TO 88
 985 CONTINUE
C-
C- BEGIN COMPUTATION FOR GRAPHICAL OUTPUT
C-
 MT=1
 DO 44 I=1,N
 44 AA(I)=PI(I)
 WRITE(IGRAF,2222)
 2222 FORMAT(1H1)
 WRITE(IGRAF,1003) (TITLE(I),I=1,50)
 WRITE(IGRAF,1114)
 1114 FORMAT(25X,"* PERFORMANCE INDEX",/
-,1X,"T",23X,"+ DIRECTIONAL ANGLE")
 WRITE(IGRAF,90)
 90 FORMAT(1X,"I",1X,"S",/1X,"M",1X,"E",3X,
-"-100",2X,"-80",2X,"-60",3X,"-40",2X,"-20",
-3X,"0",3X,"+20",2X,"+40",2X,"+60",2X,"+80",2X,"+100")
```

```
DO 66 J=10,60
BE(J)=DOT
66 CONTINUE
DO 666 J=10,60,5
BE(J)=PLUS
666 CONTINUE
WRITE(IGRAF,77)  (BE(J),J=10,60)
77 FORMAT(1X,"E",1X,"C",5X,51A1)
DO 88 I=1,N
DO 99 J=10,60
BE(J)=BLANK
99 CONTINUE
BE(35)=DOT
BE(60)=STATE(I)
BE(10)=STATE(I)
IF(DA(I).GT.99.9.OR.DA(I).LT.-99.9) GO TO 4123
IK=.25*DA(I)+35.5
BE(IK)=PLUS
GO TO 4133
4123 BE(35)=XXX
4133 CONTINUE
IF(AA(I).GT.99.9.OR.AA(I).LT.-99.9)GO TO 9876
J=.25*AA(I)+35.5
BE(J)=STAR
GO TO 7654
9876 BE(35)=XXX
7654 CONTINUE
IF(KOUNT.EQ.45)  WRITE(IGRAF,1003)  (TITLE(KK),KK=1,50)
IF(KOUNT.EQ.45)  WRITE(IGRAF,1114)
IF(KOUNT.EQ.45)  WRITE(IGRAF,90)
IF(KOUNT.EQ.45)  KOUNT=0
KOUNT=KOUNT+1
WRITE(IGRAF,11)  MT,(BE(J),J=10,60)
11 FORMAT(I4,5X,51A1)
MT=MT+1
88 CONTINUE
PRINT 411,IFIL
411 FORMAT(5X,"ANOTHER FILE DONE ", I4)
WRITE(4,786) N
786 FORMAT(2X,I4)
WRITE(4,785)  (TITLE(JK),JK=1,50)
785 FORMAT(2X,50A1)
DO 42 I=1,N
IF(ABS(PI(I)).GT.99.9) PI(I)=0.
42 CONTINUE
WRITE(4,789)  (PI(I),I=1,N)
789 FORMAT(50(2X,9(F6.2,","),F6.2/))
DO 1141 J=1,N
IF(STATE(J).EQ.OFWEP) ISTAT(J)=1
IF(STATE(J).EQ.OFF) ISTAT(J)=2
IF(STATE(J).EQ.NUT) ISTAT(J)=3
IF(STATE(J).EQ.DEF) ISTAT(J)=4
IF(STATE(J).EQ.DEFAT) ISTAT(J)=5
1141 CONTINUE
WRITE(4,790)  (ISTAT(I),I=1,N)
790 FORMAT(50(2X,9(I1,","),I1/))
```

```
IFIL=IFIL+1
IF(IFIL.LE.NFILES) GO TO 86
PRINT 8111
8111 FORMAT(//////////5X,"REQUIRED FILE KEEPING TO SAVE DATA\\
    \\ IS-"/
-"LOAD YOUR DATA FILE"/"ADD REF"/"SAVE"/"REMOVE REF,ACM"/
-"MAKE ACM AND REF"/"SAVE"/////"TH-TH-THATS ALL FOLKS")
8765 CALL EXIT
END

END QUIKLST 4.2 SEC.
```

PAIRED ANALYSIS PROGRAM OUTPUT

FOR EXAMPLE DATA SET

```
R PFINDX_
 RUNNING

     HOW MANY FILES AM I LOOKING AT
?1_
     WHERE DO YOU WANT DATA OUT, 1=HERE, 5=PRINTEROTHERS=NONE
?1_
     WHERE DO YOU WANT A GRAPH, 1=HERE, 5=PRINTEROTHERS=NONE
?1_
```

```
A1M553Y A/C1 F4 TO A/C3 A4 ONE-ON-ONE
1          A1M553Y A/C1 F4 TO A/C3 A4 ONE-ON-ONE
        INPUT CONSTANTS FOR THIS RUN
         FIGHTER OFFENSIVE  MAX RANGE    24000.0 TARGET =   30000.0
         FIGHTER OPT MISSILE RANGE        6000.0 TARGET =    7500.0
         FIGHTER MINIMUM RANGE (GUN)       500.0 TARGET =     800.0
         FIGHTER GUN ENVELOPE RMAX        3000.0 TARGET =    3500.0
         FIGHTER ENERGY RELEVENCE         0.5000 TARGET =    0.7500
         FIGHTER INTER-ENVELOPE PENAL     0.0250 TARGET =    0.0500
        OFFENSIVE ATA=       60.0 AOT=       90.0
        OFF WEP ATA=       5.0AOT=      40.0
        OFF WEP RMAX=     9000.0RMIN=     3000.0
        FIGHT NUETRAL BEYOND    18000.0 RANGE
```

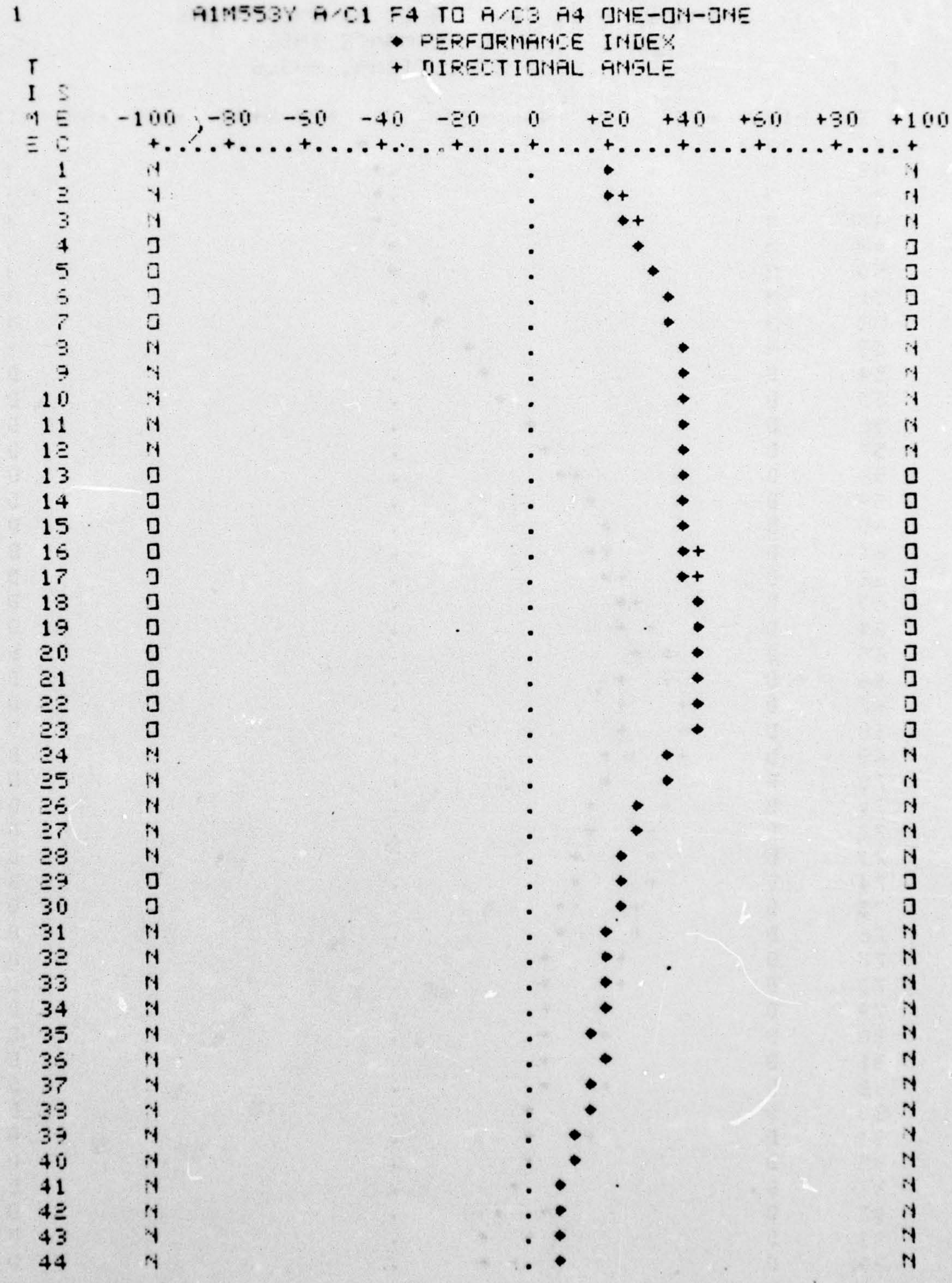
TIME	DIR ANG	NRG FN	RNG FN	PERF INDEX	STATE
1	20.00	1.0360	0.0500	19.68	N
2	23.33	0.9333	0.0277	21.17	N
3	26.11	0.9572	0.0168	24.57	N
4	28.89	0.9942	0.0113	28.39	O
5	31.67	0.9946	0.0086	31.22	O
6	34.44	0.9946	0.0075	34.00	O
7	36.11	0.9938	0.0075	35.62	O
8	38.89	0.9943	0.0064	38.42	N
9	40.56	0.9889	0.0101	39.70	N
10	40.56	0.9846	0.0127	39.43	N
11	41.67	0.9811	0.0159	40.23	N
12	41.67	0.9785	0.0196	39.97	N
13	40.56	0.9792	0.0237	38.77	O
14	41.67	0.9798	0.0272	39.71	O
15	41.67	0.9825	0.0297	39.72	O
16	42.22	0.9839	0.0307	40.27	O
17	43.33	0.9879	0.0298	41.54	O
18	43.89	0.9904	0.0271	42.29	O
19	43.89	0.9948	0.0231	42.65	O
20	45.00	0.9989	0.0187	44.11	O
21	44.44	0.9999	0.0143	43.80	O
22	42.78	1.0016	0.0105	42.39	O
23	42.78	1.0018	0.0075	42.53	O
24	37.78	1.0016	0.0053	37.64	N
25	34.44	1.0012	0.0037	34.36	N
26	29.44	1.0008	0.0027	29.39	N
27	26.67	1.0006	0.0020	26.63	N
28	24.44	1.0005	0.0018	24.41	N
29	25.00	1.0004	0.0023	24.95	O
30	22.78	1.0004	0.0027	22.73	O
31	20.56	1.0005	0.0023	20.52	N
32	18.33	1.0008	0.0018	18.31	N
33	21.11	1.0012	0.0019	21.10	N
34	20.00	1.0018	0.0024	19.99	N
35	15.00	1.0035	0.0031	15.01	N
36	20.00	1.0053	0.0040	20.02	N
37	15.56	1.0077	0.0053	15.59	N
38	15.00	1.0126	0.0070	15.08	N
39	12.78	1.0177	0.0091	12.89	N
40	11.11	1.0245	0.0115	11.25	N
41	9.44	1.0328	0.0143	9.62	N
42	6.67	1.0400	0.0171	6.82	N
43	8.89	1.0472	0.0197	9.12	N
44	9.44	1.0503	0.0220	9.70	N

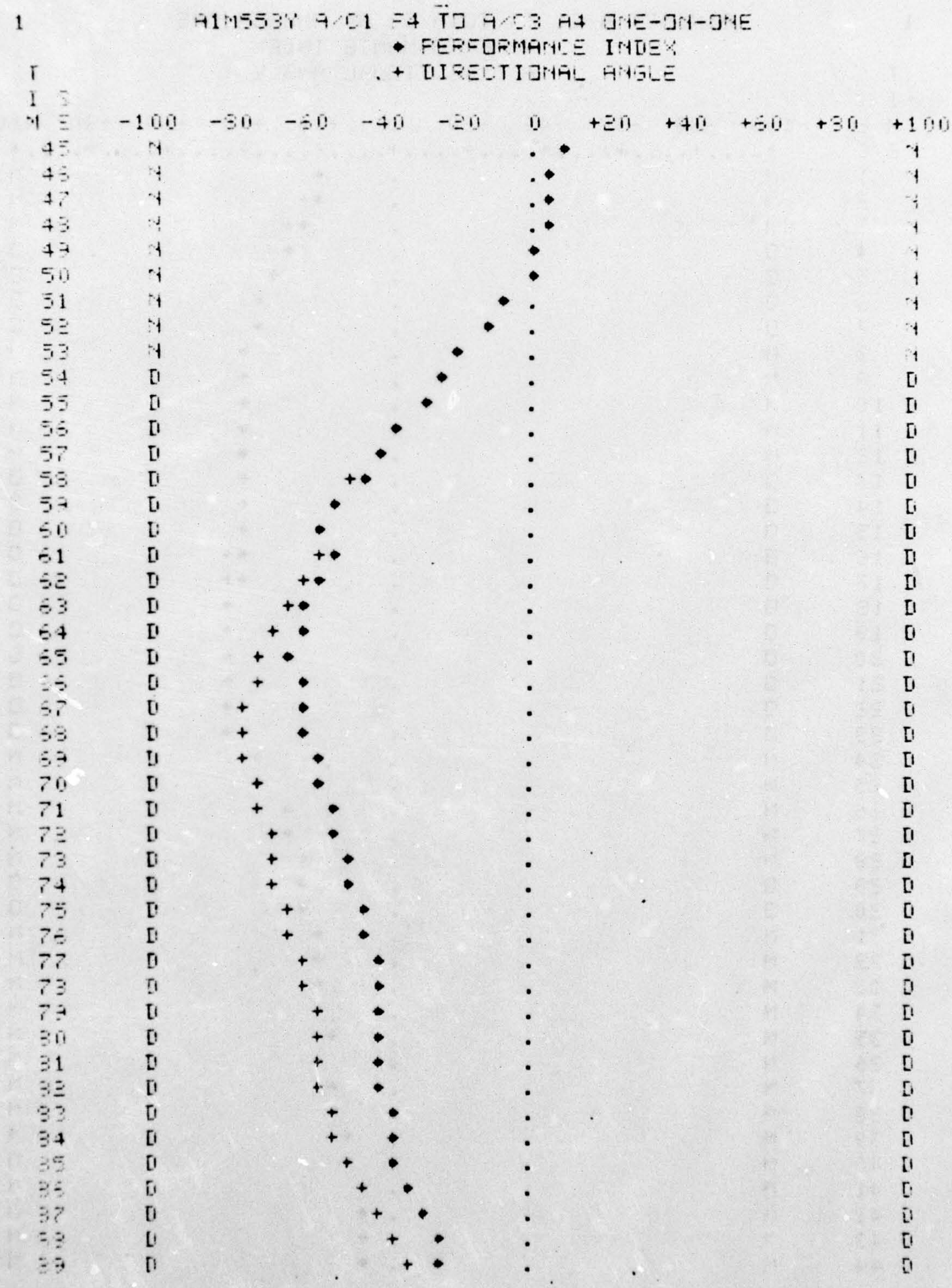
1 A1M553Y A/C1 F4 TO A/C3 A4 ONE-ON-ONE

TIME	DIR ANG	NRG FN	RNG FN	PERF INDEX	STATE
45	7.22	1.0556	0.0237	7.44	N
46	5.00	1.0578	0.0244	5.16	N
47	4.44	1.0602	0.0242	4.60	N
48	2.78	1.0587	0.0231	2.87	N
49	0.00	1.0573	0.0214	0.00	N
50	-1.67	0.9765	0.0065	-1.62	N
51	-7.22	0.9779	0.0060	-7.02	N
52	-12.22	0.9787	0.0054	-11.90	N
53	-18.89	0.9797	0.0049	-18.41	N
54	-24.44	0.9796	0.0046	-23.84	D
55	-28.89	0.9792	0.0044	-28.16	D
56	-35.00	0.9779	0.0044	-34.08	D
57	-40.56	0.9753	0.0046	-39.37	D
58	-47.22	0.9712	0.0050	-45.63	D
59	-52.22	0.9656	0.0057	-50.14	D
60	-57.78	0.9590	0.0066	-55.05	D
61	-57.22	0.9499	0.0078	-53.93	D
62	-61.11	0.9384	0.0093	-56.81	D
63	-64.44	0.9236	0.0113	-58.85	D
64	-67.22	0.9073	0.0138	-60.15	D
65	-72.22	0.8877	0.0169	-63.03	D
66	-73.89	0.8549	0.0238	-61.66	D
67	-75.56	0.8365	0.0289	-61.38	D
68	-75.00	0.8173	0.0346	-59.17	D
69	-75.00	0.8045	0.0412	-57.85	D
70	-73.89	0.7892	0.0481	-55.51	D
71	-72.22	0.7788	0.0549	-53.16	D
72	-70.00	0.7697	0.0620	-50.53	D
73	-68.33	0.7574	0.0690	-48.18	D
74	-66.67	0.7510	0.0755	-46.29	D
75	-65.00	0.7432	0.0813	-44.38	D
76	-62.22	0.7411	0.0863	-42.13	D
77	-61.11	0.7499	0.0901	-41.70	D
78	-58.89	0.7583	0.0931	-40.49	D
79	-57.22	0.7677	0.0953	-39.74	D
80	-55.56	0.7745	0.0965	-38.87	D
81	-54.44	0.7752	0.0965	-38.13	D
82	-54.44	0.7733	0.0958	-38.07	D
83	-53.33	0.7725	0.0943	-37.31	D
84	-51.67	0.7747	0.0922	-36.34	D
85	-49.44	0.7761	0.0888	-34.96	D
86	-45.00	0.7839	0.0839	-32.32	D
87	-40.00	0.7907	0.0790	-29.13	D
88	-34.44	0.7979	0.0744	-25.44	D
89	-31.67	0.8052	0.0702	-23.71	D

A1M553Y A/C1 F4 TO A/C3 A4 ONE-ON-ONE

TIME	DIR ANG	NRG FN	RNG FN	PERF INDEX	STATE
90	-28.33	0.8061	0.0672	-21.31	D
91	-23.33	0.8109	0.0652	-17.69	N
92	-18.33	0.8179	0.0633	-14.05	N
93	-15.56	0.8200	0.0626	-11.96	N
94	-10.56	0.8236	0.0625	-8.15	N
95	-7.78	0.8260	0.0632	-6.02	N
96	-4.44	0.8258	0.0649	-3.43	N
97	-1.67	0.8271	0.0678	-1.28	N
98	-0.56	0.8272	0.0716	-0.43	N


1
A1M553Y A/C1 F4 TO A/C3 A4 ONE-ON-ONE
◆ PERFORMANCE INDEX
+ DIRECTIONAL ANGLE
TIME
SEC
-100 -80 -60 -40 -20 0 +20 +40 +60 +80 +100


1
A1M553Y A/C1 F4 TO A/C3 A4 ONE-ON-ONE
◆ PERFORMANCE INDEX
. + DIRECTIONAL ANGLE
T
I S
M E
-100 -80 -60 -40 -20 0 +20 +40 +60 +80 +100

```
1           A1M553Y A/01 F4 TO A/03 94 ONE-ON-ONE
                         ◆ PERFORMANCE INDEX
 T                       + DIRECTIONAL ANGLE
 I S
 M E   -100  -80  -60  -40  -20   0  +20  +40  +60  +80  +100
  90     D                 + ◆    .                        D
  91     N                  + ◆   .                        N
  92     N                   +◆   .                        N
  93     N                    +◆  .                        N
  94     N                     +◆ .                        N
  95     N                      ◆ .                        N
  96     N                       ◆.                        N
  97     N                        ◆                        N
  98     N                        ◆                        N
     ANOTHER FILE DONE     1




     REQUIRED FILE KEEPING TO SAVE DATA IS-
LOAD YOUR DATA FILE
ADD REF
SAVE
REMOVE REF,ACM
MAKE ACM AND REF
SAVE



TH-TH-THATS ALL FOLKS


 END PFINDX 14.9 SEC.
```

SECTION ANALYSIS PROGRAM

```
L SECT12_

FILE:SECT12 -08/16/76 10:01 AM.

$ERRMES
FILE  1=TRMNL,UNIT=REMOTE
FILE  2=ACM,UNIT=DISK
FILE  3=BCM,UNIT=DISK
FILE  4=REF,UNIT=DISK
FILE  5=RANDY,UNIT=PRINTER BACKUP DISK
C-
C- REFERENCES  ************  REFERENCES  ********** REFERENCES
C-     1--- NATC RPT SA-C3R-76 OF 26 JAN 1976
C-     2--- NATC RPT TM-76-1SA OF 16 JUL 1976
C-     3--- CENTER FOR NAVAL ANALYSES RPT CRC 274 OF NOV 1974
C-
 DIMENSION R1(500),R2(500),ES11(500),ES12(500),ES21(500),
-ES22(500),AOT1(500),AOT2(500),ATA1(500),ATA2(500),
-TITLE1(50),TITLE2(50),PI1(500),PI2(500),ISTAT1(500),
-ISTAT2(500),PIS(500),PHI(500),STATE(500)
 DIMENSION AA(500),BE(500)
 DIMENSION CONCO(500)
 DIMENSION ISTAT(500)
 DATA BLANK,DOT,STAR,XXX,PLUS/" ",".","*","X","+"/
 DATA DOLL/"$"/
 DATA OFWEP,OFF,DEF,NUT,DEFAT,TRADE/"W","O","D","N","F","T"/
C-
C- MANEUVER CONVERSION DATA  W=OFFENSIVE WEAPONS
C-                           O=OFFENSIVE
C-                           N=NEUTRAL
C-                           D=DEFENSIVE
C-                           F=FATAL DEFENSIVE
C-                           T=TRADEOFF
C-
C-
 PRINT 433
 433 FORMAT(5X,"HOW MANY FILES AM I LOOKING AT ")
 READ(1,/) NFILES
 IFIL=1
 PRINT 434
 434 FORMAT(5X,"WHERE DO YOU WANT DATA OUT, 1=HERE, 5=PRINTER",
-"OTHERS=NONE")
 READ(1,/) IPRINT
 PRINT 435
 435 FORMAT(5X,"WHERE DO YOU WANT A GRAPH, 1=HERE, 5=PRINTER",
-"OTHERS=NONE")
 READ(1,/) IGRAF
 WRITE(1,775)
 86 CONTINUE
 775 FORMAT(2X,"GO TO SLEEP, I WILL CALL WHEN I AM READY")
C-
C- BEGIN INPUT FROM PERFORMANCE INDEX PROGRAM
C- PAIR 1 DATA IS LOCATED IN DISK FILE ACM
C- PAIR 2 DATA IS LOCATED IN DISK FILE BCM
C-
 READ(2,/) N1
 READ(2,123) (TITLE1(I),I=1,50)
 123 FORMAT(50A1)
```

```
 READ(2,/) (PI1(I),I=1,N1)
 READ(2,/) (ISTAT1(I),I=1,N1)
 READ(3,/) N2
 READ(3,123) (TITLE2(I),I=1,50)
 READ(3,/) (PI2(I),I=1,N2)
 READ(3,/) (ISTAT2(I),I=1,N2)
 N=N1
 IF(N2.LT.N1) N=N2
 PHIT=0.
C-
C- BEGIN COMPUTATION OF SECTION PERFORMANCE INDEX BY
C- MAGNITUDE SUM METHOD OF REFERENCE 2
C-
 DO 10 I=1,N
 PI1SQ=PI1(I)*ABS(PI1(I))
 PI2SQ=PI2(I)*ABS(PI2(I))
 RAD=ABS(PI1SQ+PI2SQ)
 IF(ABS(RAD).LT.0.1) PIS(I)=0.
 IF(ABS(RAD).LT.0.1) GO TO 3
 SIGN=(PI1SQ+PI2SQ)/RAD
 PIS(I)=SIGN*SQRT(RAD/2.)
 3 CONTINUE
C-
C- BEGIN COMPUTATION OF CONVERSION COEFFICIENT AS OUTLINED
C- IN THE TEXT
C-
 IF(ABS(PI1(I)).GT.100.) CONCO(I)=0.
 IF(ABS(PI2(I)).GT.100.) CONCO(I)=0.
 IF(ABS(PI1(I)).GT.100..OR.ABS(PI2(I)).GT.100.) GO TO 9
 IF((PI1(I).GT.30..AND.PI2(I).LT.30.).OR.(PI2(I).GT.30..AND.
-PI1(I).LT.30.)) GO TO 5
 CONCO(I)=PIS(I)
 GO TO 9
 5 IF(ABS(PI1(I)).LT.75..AND.ABS(PI2(I)).LT.75.) GO TO 6
 IF(ABS(PI1(I)).LT.0.1) PI1(I)=0.1
 IF(ABS(PI2(I)).LT.0.1) PI2(I)=0.1
 IF(ABS(PI1(I)).GT.ABS(PI2(I))) CONCO(I)=SQRT(PI1(I)**2*
-(1.-ABS(PI2(I)/400.)))*PI1(I)/ABS(PI1(I))
 IF(ABS(PI2(I)).GT.ABS(PI1(I))) CONCO(I)= SQRT(PI2(I)**2*
-(1.-ABS(PI1(I)/400.)))*PI2(I)/ABS(PI2(I))
 IF(ABS(PI1(I)).GT.75..AND.ABS(PI2(I)).GT.75.) CONCO(I)=PIS(I)
 GO TO 9
 6 IF(PI1(I).GT.PI2(I))
-CONCO(I)=SQRT(PI1(I)**2*(1.-ABS(PI2(I))/75.))
 IF(PI2(I).GT.PI1(I))
-CONCO(I)=SQRT(PI2(I)**2*(1.-ABS(PI1(I))/75.))
 9 XK1=ABS(PI1(I)-PIS(I))
 XK2=ABS(PI2(I)-PIS(I))
 DEN=XK2
 XNUM=XK1
 IF(XK1.GT.XK2) DEN=XK1
 IF(XK1.GT.XK2) XNUM=XK2
 IF(DEN.LT.0.1) PHI(I)=0.
 IF(DEN.LT.0.1) GO TO 10
 PHI(I)=XNUM/DEN
 10 PHIT=PHIT+PHI(I)
 PHIT=PHIT/N
```

```
C-
C- COMPUTE ACM STATE FOR TWO ON ONE PER REFERENCE 3
C-
 DO 20 I=1,N
 STATE(I)=DEF
 IF(ISTAT1(I).EQ.1.AND.ISTAT2(I).NE.5) STATE(I)=OFWEP
 IF(ISTAT2(I).EQ.1.AND.ISTAT1(I).NE.5) STATE(I)=OFWEP
 IF(ISTAT1(I).EQ.1.AND.ISTAT2(I).EQ.5) STATE(I)=TRADE
 IF(ISTAT2(I).EQ.1.AND.ISTAT1(I).EQ.5) STATE(I)=TRADE
 IF(ISTAT2(I).EQ.2.OR.ISTAT1(I).EQ.2) STATE(I)=OFF
 IF(ISTAT1(I).EQ.3.AND.ISTAT2(I).EQ.3) STATE(I)=NUT
 IF(ISTAT1(I).EQ.5.AND.ISTAT2(I).NE.1) STATE(I)=DEFAT
 IF(ISTAT2(I).EQ.5.AND.ISTAT1(I).NE.1) STATE(I)=DEFAT
 20 CONTINUE
 SUM=0.
 DO 30 J=1,N
 30 SUM=SUM+PHI(J)**2
 COORD=1.-SQRT(SUM/N)
C-
C- BEGIN PRINT OF OUTPUT
C-
 IF(IPRINT.NE.1.AND.IPRINT.NE.5) GO TO 40
 WRITE(IPRINT,1003) (TITLE1(I),I=1,50),(TITLE2(I),I=1,50)
 1003 FORMAT(1H1,10X,50A1/11X,50A1)
 WRITE(IPRINT,301)
 301 FORMAT(5X,"TIME    PERF    PERF    PERF    CONVERSION \\
     \\ STATE"/
-             5X,"        INDEX   INDEX   INDEX   COEFFICNT \\
     \\ (SECTION)"/
-             5X,"        PAIR1   PAIR2   SECTN")
 KOUNT=1
C-
C- BEGIN GRAPHICAL COMPUTATIONS FOR OUTPUT GRAPH
C-
 DO 40 J=1,N
 IF(KOUNT.EQ.45.) WRITE(IPRINT,1003) (TITLE1(I),I=1,50),
-(TITLE2(I),I=1,50)
 IF(KOUNT.EQ.45) WRITE(IPRINT,301)
 IF(KOUNT.EQ.45) KOUNT=0
 KOUNT=KOUNT+1
 WRITE(IPRINT,278) J,PI1(J),PI2(J),PIS(J),CONCO(J),STATE(J)
 278 FORMAT(5X,I3,4(3X,F6.2),9X,A1)
 40 CONTINUE
 IF(IPRINT.EQ.1.OR.IPRINT.EQ.5) WRITE (IPRINT,909) PHIT,COORD
 909 FORMAT(10X,"SECT COORD = ",F6.4,5X,"CONSISTENCY = ",F6.4)
 MT=1
 DO 44 I=1,N
 44 AA(I)=PIS(I)
 IF(IGRAF.NE.1.AND.IGRAF.NE.5) GO TO 50
 KOUNT=1
 WRITE(IGRAF,1003) (TITLE1(KK),KK=1,50),(TITLE2(KK),KK=1,50)
 WRITE(IGRAF,1114)
 1114 FORMAT(25X,"* SECTION INDEX  + FOR TRADE-OFF",/,25X,
-"$ CONVERSION COEFFICIENT ",/,1X,"T")
 WRITE(IGRAF,90)
 90 FORMAT(1X,"I",1X,"S",/1X,"M",1X,"E",3X,
-"-100",2X,"-80",2X,"-60",2X,"-40",2X,"-20",
```

```
-3X,"0",3X,"+20",2X,"+40",2X,"+60",2X,"+80",2X,"+100")
 DO 66 J=10,60
 BE(J)=DOT
 66 CONTINUE
 DO 666 J=10,60,5
 BE(J)=PLUS
 666 CONTINUE
 WRITE(IGRAF,77) (BE(J),J=10,60)
 77 FORMAT(1X,"E",1X,"C",5X,51A1)
 DO 88 I=1,N
 DO 99 J=10,60
 BE(J)=BLANK
 99 CONTINUE
 BE(35)=DOT
 BE(60)=STATE(I)
 BE(10)=STATE(I)
 IF(CONCO(I).GT.99.9.OR.CONCO(I).LT.-99.9) GO TO 4123
 K=.25*CONCO(I)+35.5
 BE(K)=DOLL
 GO TO 4133
 4123 BE(35)=XXX
 4133 CONTINUE
 IF(AA(I).GT.99.9.OR.AA(I).LT.-99.9)GO TO 9876
 J=.25*AA(I)+35.5
 BE(J)=STAR
 IF((PI1(I).GT.75..AND.PI2(I).LT.-75.).OR.(PI1(I).LT.-75..
-AND.PI2(I).GT.75.)) BE(J)=PLUS
 GO TO 7654
 9876 BE(35)=XXX
 7654 CONTINUE
 IF(KOUNT.EQ.45) WRITE(IGRAF,1003) (TITLE1(KK),KK=1,50),
-(TITLE2(KK),KK=1,50)
 IF(KOUNT.EQ.45) WRITE(IGRAF,1114)
 IF(KOUNT.EQ.45) WRITE(IGRAF,90)
 IF(KOUNT.EQ.45) KOUNT=0
 KOUNT=KOUNT+1
 WRITE(IGRAF,11) MT,(BE(J),J=10,60)
 11 FORMAT(I4,5X,51A1)
 MT=MT+1
 88 CONTINUE
 50 CONTINUE
 WRITE(1,776)
 776 FORMAT(2X,"WAKE UP, I HAVE DONE ANOTHER FILE")
 WRITE(1,123) (TITLE1(I),I=1,50)
C-
C- CREATE AN OUTPUT FILE ON DISK (REF) FOR FURTHER ANALYSIS
C-
 WRITE(4,777) N
 777 FORMAT(2X,I4)
 WRITE(4,789) (PIS(I),I=1,N)
 WRITE(4,787) (TITLE1(I),I=1,50),(TITLE2(I),I=1,50)
 787 FORMAT(2X,50A1,/,2X,50A1)
 789 FORMAT(50(2X,9(F6.2,","),F6.2/))
 DO 1141 J=1,N
 IF(STATE(J).EQ.OFWEP) ISTAT(J)=1
 IF(STATE(J).EQ.OFF) ISTAT(J)=2
```

```
IF(STATE(J).EQ.NUT) ISTAT(J)=3
IF(STATE(J).EQ.DEF) ISTAT(J)=4
IF(STATE(J).EQ.DEFAT) ISTAT(J)=5
IF(STATE(J).EQ.TRADE) ISTAT(J)=6
1141 CONTINUE
WRITE(4,790) (ISTAT(I),I=1,N)
790 FORMAT(50(2X,9(I1,","),I1/))
WRITE(4,789) (CONCO(I),I=1,N)
IFIL=IFIL+1
IF(IFIL.LE.NFILES) GO TO 86
8765 CALL EXIT
END
```

END QUIKLST 3.1 SEC.

SECTION ANALYSIS PROGRAM OUTPUT
FOR EXAMPLE DATA SET

```
R SECT12_
 RUNNING

      HOW MANY FILES AM I LOOKING AT
?1_
      WHERE DO YOU WANT DATA OUT, 1=HERE, 5=PRINTEROTHERS=NONE
?1_
      WHERE DO YOU WANT A GRAPH, 1=HERE, 5=PRINTEROTHERS=NONE
?1_
  GO TO SLEEP, I WILL CALL WHEN I AM READY
```

1 ACM564Y 1 TO 3 2 ON 1 TEST 5/40,3-9K,60/90,18KM
BCM564 2 ON 1, 2 TO 3 TEST 5/40,3-9K,60/90,18KMAX

TIME	PERF INDEX PAIR1	PERF INDEX PAIR2	PERF INDEX SECTN	CONVERSION COEFFICNT	STATE (SECTION)
1	-10.42	-2.58	-7.59	-7.59	N
2	-14.57	-3.56	-10.61	-10.61	N
3	-17.59	-4.27	-12.80	-12.80	N
4	-19.94	-5.30	-14.59	-14.59	N
5	-21.58	-6.20	-15.88	-15.88	N
6	-22.56	-7.43	-16.30	-16.30	N
7	-22.44	-7.61	-16.76	-16.76	N
8	-22.60	-8.43	-17.06	-17.06	N
9	-22.16	-8.71	-16.94	-16.84	N
10	-22.14	-8.81	-16.85	-16.85	N
11	-21.68	-8.34	-16.43	-16.43	N
12	-20.81	-9.51	-16.18	-16.18	N
13	-19.16	-8.21	-14.74	-14.74	N
14	-17.52	-6.07	-13.11	-13.11	N
15	-16.62	-4.71	-12.21	-12.21	N
16	-14.44	-3.49	-10.50	-10.50	N
17	-13.40	-2.09	-9.59	-9.59	N
18	-11.85	-0.54	-8.39	-8.39	N
19	-10.50	1.12	-7.38	-7.38	N
20	-9.32	3.34	-6.15	-6.15	N
21	-7.52	6.62	-2.52	-2.52	N
22	-6.89	8.11	3.02	3.02	N
23	-5.77	18.10	12.13	12.13	N
24	-4.20	22.07	15.32	15.32	N
25	-1.71	28.42	20.06	20.06	N
26	0.00	30.27	21.40	30.27	N
27	1.96	31.33	22.20	30.92	N
28	3.34	26.11	18.61	18.61	N
29	4.46	19.49	14.14	14.14	N
30	5.77	15.08	11.42	11.42	N
31	5.94	15.70	11.87	11.87	N
32	6.46	16.87	12.77	12.77	N
33	7.77	12.41	10.35	10.35	N
34	9.31	8.49	8.90	8.90	N
35	10.67	5.05	8.36	8.36	N
36	12.06	0.00	8.53	8.53	N
37	13.10	-6.01	8.23	3.23	N
38	14.35	-14.26	1.13	1.13	N
39	15.85	-19.25	-7.72	-7.72	N
40	18.71	-22.05	-8.25	-8.25	N
41	21.31	-27.62	-12.42	-12.42	N
42	24.39	-34.30	-17.06	-17.06	D
43	28.84	-38.72	-18.27	-18.27	D
44	32.72	-45.28	-22.13	20.60	D

1 ACM564Y 1 TO 3 2 ON 1 TEST 5/40,3-9K,60/90,18KM
BCM564 2 ON 1, 2 TO 3 TEST 5/40,3-9K,60/90,18KMAX

TIME	PERF INDEX PAIR1	PERF INDEX PAIR2	PERF INDEX SECTN	CONVERSION COEFFICNT	STATE (SECTION)
45	36.95	-51.77	-25.64	20.56	D
46	41.69	-57.70	-28.21	20.02	D
47	46.27	-63.68	-30.94	17.98	D
48	50.15	-69.74	-34.27	13.28	D
49	53.19	-74.23	-36.61	5.99	O
50	56.42	-79.85	-39.96	-74.00	F
51	61.57	-82.20	-38.51	-75.61	F
52	65.16	-82.88	-36.22	-75.83	F
53	70.45	-84.62	-33.15	-76.91	F
54	74.67	-85.21	-29.03	-76.35	F
55	78.10	-86.31	-25.98	-25.98	O
56	79.97	-87.94	-25.87	-25.87	O
57	79.37	-86.21	-23.80	-23.80	O
58	85.73	-80.62	20.62	20.62	O
59	86.90	-76.11	29.66	29.66	O
60	84.26	-71.60	31.41	76.35	O
61	82.32	-65.41	35.34	75.29	O
62	80.86	-58.66	39.35	74.70	O
63	78.21	-51.32	41.73	73.02	O
64	75.86	-40.72	45.26	71.90	O
65	72.02	-28.03	46.91	56.99	O
66	68.04	-19.76	46.04	58.39	O
67	62.60	-10.02	43.69	58.27	O
68	59.06	2.35	41.79	59.13	O
69	51.70	9.44	37.16	48.34	O
70	44.79	22.33	35.39	37.53	O
71	37.79	29.36	33.94	29.48	O
72	32.66	34.41	33.55	33.55	N
73	26.70	35.50	31.41	28.49	N
74	23.63	34.61	29.63	23.64	N
75	23.84	28.99	26.54	26.54	N
76	22.81	26.18	24.55	24.55	N
77	21.74	22.81	22.28	22.28	N
78	20.69	21.82	21.26	21.26	N
79	20.23	24.07	22.23	22.23	N
80	20.61	22.91	21.79	21.79	N
81	20.98	21.58	21.28	21.28	N
82	21.59	20.57	21.09	21.09	N
83	22.69	18.70	20.79	20.79	O
84	22.61	16.87	19.95	19.95	N
85	24.16	15.08	20.14	20.14	N
86	25.72	12.95	20.36	20.36	N
87	26.18	11.08	20.10	20.10	N
88	27.79	9.74	20.32	20.32	N
89	31.40	8.29	22.96	29.61	N

1 ACM564Y 1 TO 3 2 ON 1 TEST 5/40,3-9K,60/90,18KM
BCM564 2 ON 1, 2 TO 3 TEST 5/40,3-9K,60/90,18KMAX

TIME	PERF INDEX PAIR1	PERF INDEX PAIR2	PERF INDEX SECTN	CONVERSION COEFFICNT	STATE (SECTION)
90	39.46	7.20	28.36	37.52	N
91	43.77	7.12	31.36	41.64	D
92	60.34	6.89	42.94	57.50	D
93	67.66	7.10	48.11	64.38	D
94	38.78	6.82	27.84	36.97	N
95	16.03	6.31	12.13	12.18	N
96	7.73	6.23	7.02	7.02	N
97	-0.55	5.70	4.01	4.01	N
98	-9.40	5.44	-5.42	-5.42	N
99	-21.05	5.09	-14.44	-14.44	N
100	-37.72	5.34	-26.40	-26.40	D
101	-53.27	5.56	-37.46	-37.46	D
102	-62.11	5.41	-43.75	-43.75	D
103	-64.73	5.48	-45.61	-45.61	D
104	-59.93	5.12	-42.22	-42.22	D
105	-55.49	5.13	-39.07	-39.07	N
106	-50.77	5.01	-35.72	-35.72	N
107	-48.95	4.54	-34.46	-34.46	N
108	-48.49	4.01	-34.17	-34.17	N
109	-45.40	3.40	-32.01	-32.01	N
110	-40.93	3.03	-28.86	-28.86	N
111	-38.62	2.68	-27.24	-27.24	N
112	-36.84	2.42	-25.99	-25.99	N
113	-35.56	2.31	-25.09	-25.09	N
114	-33.13	2.20	-23.37	-23.37	N
115	-33.36	2.28	-23.53	-23.53	N
116	-34.02	2.32	-24.00	-24.00	N
117	-34.56	2.34	-24.38	-24.38	N
118	-34.32	2.63	-24.20	-24.20	N
119	-29.77	2.97	-20.95	-20.95	N
120	-27.63	3.60	-19.37	-19.37	N
121	-25.92	4.71	-18.02	-18.02	N
122	-24.16	6.61	-16.43	-16.43	N
123	-22.40	8.72	-14.59	-14.59	N
124	-23.40	10.63	-14.74	-14.74	N
125	-23.42	13.14	-13.71	-13.71	N
126	-22.19	15.52	-11.21	-11.21	N
127	-20.39	15.03	-9.74	-9.74	N
128	-18.76	12.49	-9.90	-9.90	N
129	-18.42	10.13	-10.88	-10.88	N
130	-16.76	5.07	-11.30	-11.30	N
131	-14.47	2.47	-10.09	-10.09	N
132	-11.52	0.60	-8.13	-8.13	N
133	-8.92	4.05	-5.62	-5.62	N
134	-7.85	5.68	-3.83	-3.83	N

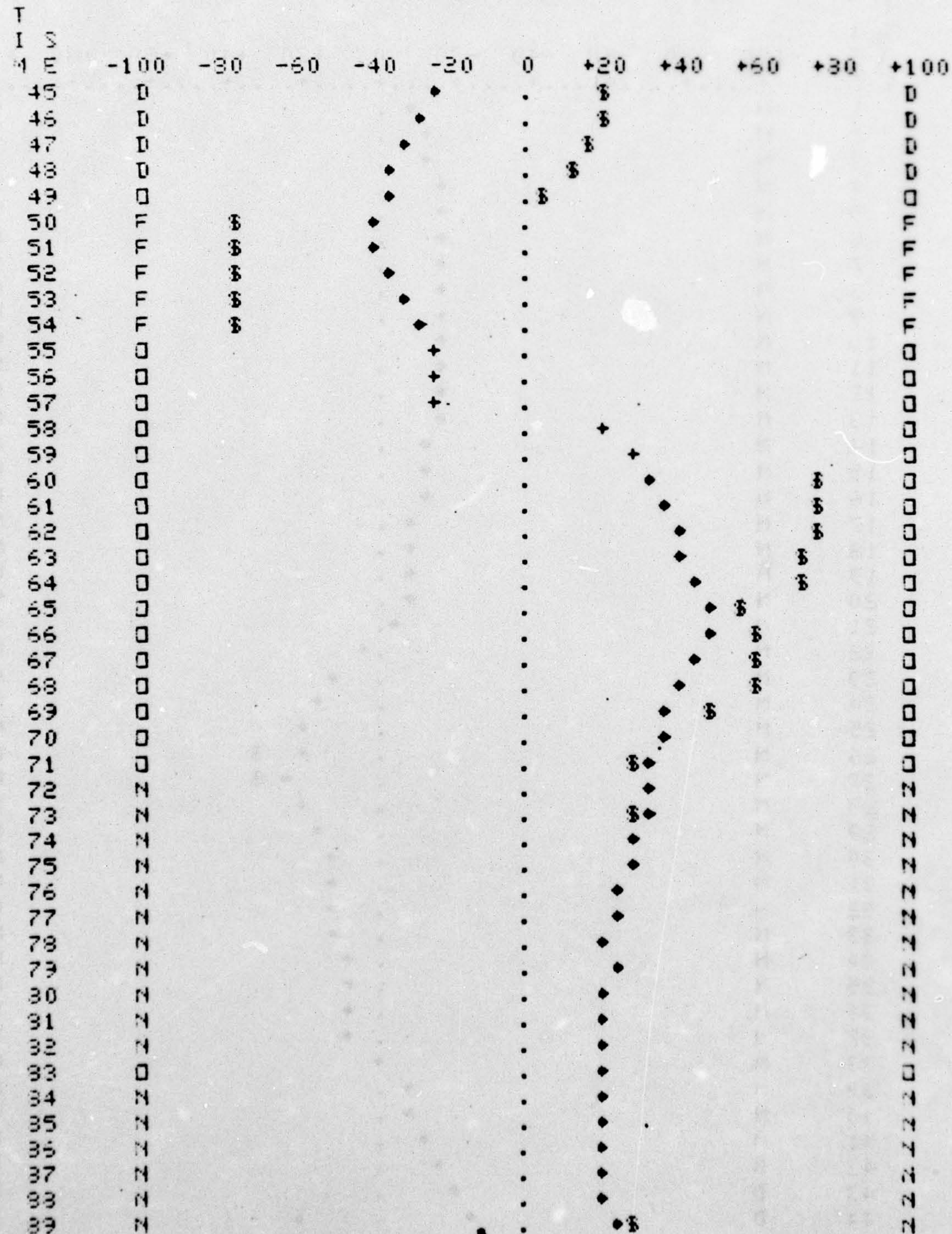
1 ACM564Y 1 TO 3 2 ON 1 TEST 5/40,3-9K,60/90,18KM
BCM564 2 ON 1, 2 TO 3 TEST 5/40,3-9K,60/90,18KMAX

TIME	PERF INDEX PAIR1	PERF INDEX PAIR2	PERF INDEX SECTN	CONVERSION COEFFICNT	STATE (SECTION)
135	-7.18	11.22	6.10	6.10	N
136	-5.00	16.18	10.88	10.88	N
137	-0.78	24.48	17.30	17.30	N
138	1.35	29.98	21.22	21.22	O
139	6.25	29.37	21.23	21.23	O
140	11.75	33.83	25.32	31.07	N
141	18.22	41.11	31.80	35.77	N
142	20.73	43.39	34.00	36.91	N
143	22.70	47.35	37.13	39.54	O
144	23.39	49.65	38.81	41.19	O
145	23.20	51.98	40.25	43.20	O
146	22.75	55.43	42.37	46.27	O
147	22.61	59.96	45.31	50.11	O
148	21.70	63.36	47.36	53.41	O
149	23.63	66.77	50.08	55.26	O
150	27.20	71.79	54.28	57.31	O
151	30.76	76.76	58.47	58.47	O
152	34.94	77.83	60.33	60.33	O
153	38.61	78.34	61.76	61.76	O
154	41.24	79.37	63.25	63.25	O
155	46.17	77.04	63.51	63.51	O
156	51.64	71.92	62.61	62.61	O
157	55.15	69.06	62.49	62.49	O
158	58.44	65.11	61.86	61.86	O
159	57.99	62.28	60.17	60.17	O
160	55.67	60.03	57.89	57.89	O
161	53.54	57.10	55.35	55.35	O
162	52.47	53.09	52.79	52.79	O
163	50.26	48.95	49.61	49.61	O
164	46.60	48.61	47.62	47.62	O

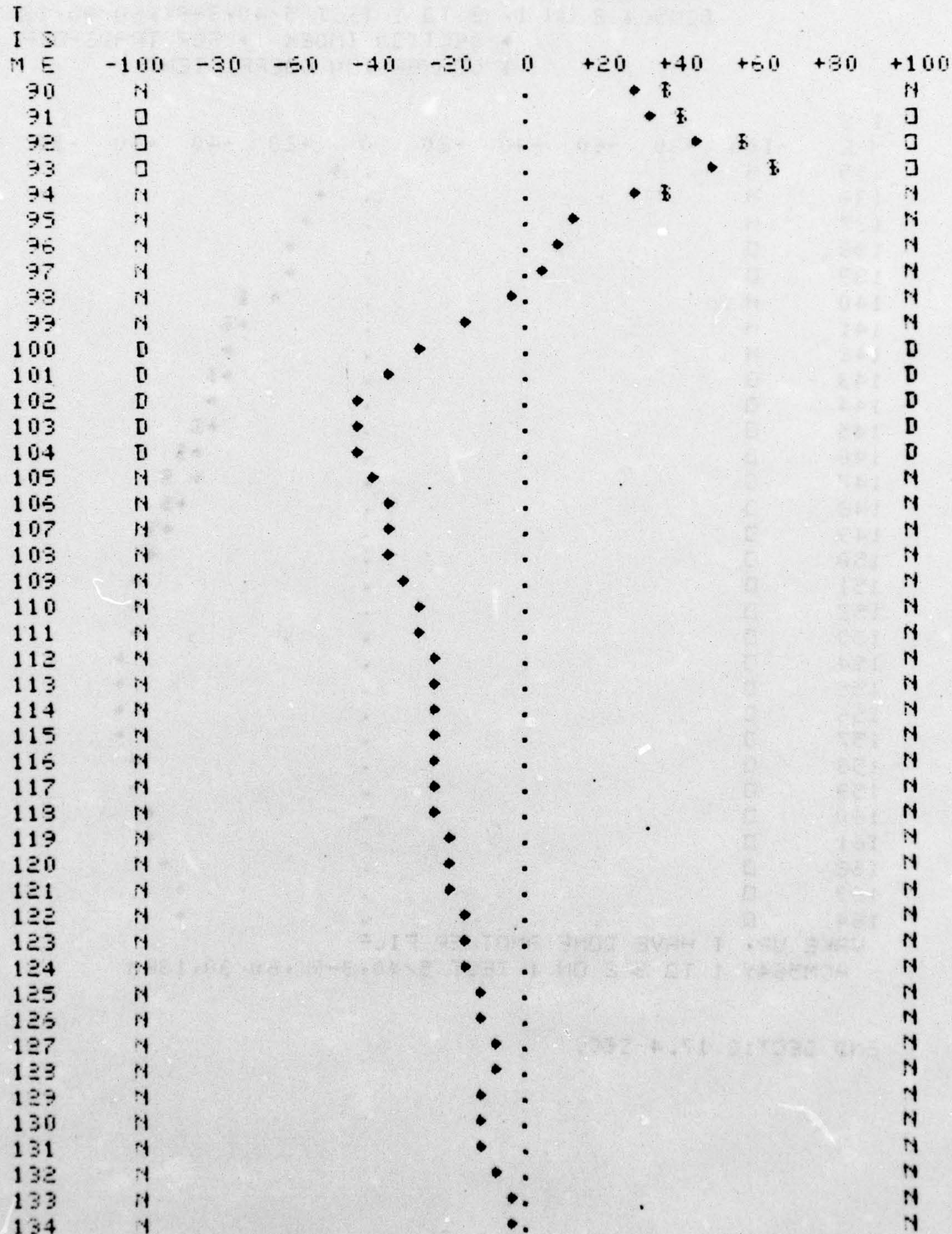
SECT COORD = 0.5645 CONSISTENCY = 0.4010

```
1                        ACM564Y 1 TO 3 2 ON 1 TEST 5/40,3-9K,60/90,18KM
                       BCM564 2 ON 1, 2 TO 3 TEST 5/40,3-9K,60/90,18KMAX
                                   ◆ SECTION INDEX   + FOR TRADE-OFF
                                   $ CONVERSION COEFFICIENT
T
I S
M E -100  -80  -60  -40  -20   0   +20  +40  +60  +80  +100
E C   +....+....+....+....+....+....+....+....+....+....+
  1   N                      ◆ .                        N
  2   N                     ◆  .                        N
  3   N                     ◆  .                        N
  4   N                    ◆   .                        N
  5   N                    ◆   .                        N
  6   N                    ◆   .                        N
  7   N                    ◆   .                        N
  8   N                    ◆   .                        N
  9   N                    ◆   .                        N
 10   N                    ◆   .                        N
 11   N                    ◆   .                        N
 12   N                    ◆   .                        N
 13   N                    ◆   .                        N
 14   N                     ◆  .                        N
 15   N                     ◆  .                        N
 16   N                     ◆  .                        N
 17   N                      ◆ .                        N
 18   N                      ◆ .                        N
 19   N                      ◆ .                        N
 20   N                      ◆ .                        N
 21   N                       ◆.                        N
 22   N                        .◆                       N
 23   N                        .  ◆                     N
 24   N                        .   ◆                    N
 25   N                        .    ◆                   N
 26   N                        .    ◆  $                N
 27   N                        .     ◆ $                N
 28   N                        .    ◆                   N
 29   N                        .   ◆                    N
 30   N                        .  ◆                     N
 31   N                        .  ◆                     N
 32   N                        .  ◆                     N
 33   N                        .  ◆                     N
 34   N                        . ◆                      N
 35   N                        . ◆                      N
 36   N                        . ◆                      N
 37   N                        . ◆                      N
 38   N                        ◆                        N
 39   N                      ◆ .                        N
 40   N                      ◆ .                        N
 41   N                     ◆  .                        N
 42   D                    ◆   .                        D
 43   D                   ◆    .                        D
 44   D                  ◆     .    $  .                D
```

1 ACM564Y 1 TO 3 2 ON 1 TEST 5/40,3-9K,60/90,18KM
BCM564 2 ON 1, 2 TO 3 TEST 5/40,3-9K,60/90,18KMAX
◆ SECTION INDEX + FOR TRADE-OFF
$ CONVERSION COEFFICIENT



1 ACM564Y 1 TO 3 2 ON 1 TEST 5/40,3-9K,60/90,18KM
BCM564 2 ON 1, 2 TO 3 TEST 5/40,3-9K,60/90,18KMAX
◆ SECTION INDEX + FOR TRADE-OFF
$ CONVERSION COEFFICIENT



1 ACM564Y 1 TO 3 2 ON 1 TEST 5/40,3-9K,60/90,18KM
BCM564 2 ON 1, 2 TO 3 TEST 5/40,3-9K,60/90,18KMAX
◆ SECTION INDEX + FOR TRADE-OFF
$ CONVERSION COEFFICIENT

```
T
I S
M E  -100 -80  -60  -40  -20   0   +20  +40  +60  +80  +100
135  N                        .  ◆                      N
136  N                        .   ◆                     N
137  N                        .    ◆                    N
138  O                        .     ◆                   O
139  O                        .     ◆                   O
140  N                        .      ◆ $                N
141  N                        .        ◆$               N
142  N                        .         ◆               N
143  O                        .         ◆$              O
144  O                        .          ◆              O
145  O                        .          ◆$             O
146  O                        .           ◆$            O
147  O                        .           ◆ $           O
148  O                        .            ◆$           O
149  O                        .             ◆$          O
150  O                        .              ◆          O
151  O                        .               ◆         O
152  O                        .               ◆         O
153  O                        .               ◆         O
154  O                        .                ◆        O
155  O                        .                ◆        O
156  O                        .                ◆        O
157  O                        .                ◆        O
158  O                        .               ◆         O
159  O                        .               ◆         O
160  O                        .              ◆          O
161  O                        .              ◆          O
162  O                        .             ◆           O
163  O                        .            ◆            O
164  O                        .            ◆            O
```

WAKE UP, I HAVE DONE ANOTHER FILE
ACM564Y 1 TO 3 2 ON 1 TEST 5/40,3-9K,60/90,18KM

END SECT12 17.4 SEC.

STOCHASTIC ANALYSIS PROGRAM

```
FILE:STACM6 -08/23/76 10:33 AM.

$ERRMES
FILE  1=TRMNL,UNIT=REMOTE
FILE  2=ACM,UNIT=DISK
FILE  3=BCM,UNIT=DISK .
FILE  4=REF,UNIT=DISK
FILE  5=RANDY,UNIT=PRINTER BACKUP DISK
FILE  6=CCM,UNIT=DISK
FILE  7=OPT,UNIT=DISK
 INTEGER GRAFOP
  DATA PLUS/"+"/
  DATA BLANK/" "/
  DATA DOT/"."/
  DATA STAR/"*"/
  DATA DOLL/"$"/
  DATA AT/"#"/
  DIMENSION TPCALE(5,51)
  DIMENSION N(40),PIS(40,300),SECTIT(40,140),ISTATS(40,300),
 -CONCO(40,300),NPAIR(80),PARTIT(80,70),PIPAIR(80,300),
 -ISTATP(80,300),A(300),B(300),KPIS(300),FPIS(250,120),
 -FREQ(300),CUMPIS(250,120),CUMP(300),PISMN(300),PISDEV(300),
 -PISM3(300),PISM4(300),ANS(4),FCC(250,120),CUMPCC(250,120)
  DIMENSION CCMN(300),CCDEV(300),CCM3(300),CCM4(300),KIPAIR(300),
 -FPIP(250,120),CUMPIP(250,120),PIPMN(300),PIPDEV(300),PIPM3(300),
 -PIPM4(300),NCS(6,6),CPS(6,6),TC(6),MXX(300),NAME1(40),NAME2(40)
  DIMENSION IFL(6),ITIS(6,300),TSCALE(6,51),TFREQ(6,51),TCUMP(6,51),
 -TMEAN(6),TDEV(6),TMOM3(6),TMOM4(6),CPP(5,5),NCP(5,5),ITIP(5,300),
 -TPFREQ(5,51),TPCUMP(5,51),TPMEAN(5),TPDEV(5),TPMOM3(5),TPMOM4(5)
  DIMENSION NAME3(40),NAME4(40)
  DIMENSION NAME5(40)
  DIMENSION IFM(6)
C- READ IN REQUIRED CONSTANTS FOR DATA MANAGEMENT
C-
  READ(7,/) NFILES,IPRINT,IGRAF,ICALC,DELTA,ICOMP
  GRAFOP=IGRAF/ABS(IGRAF)
  IGRAF=ABS(IGRAF)
  NCK=IGRAF/ICOMP
  NKC=IGRAF/ICOMP+0.999
  IF(NCK.NE.NKC) IGRAF=ICOMP
  101 FORMAT(40A1)
  READ(7,101)  (NAME1(I),I=1,40)
  READ(7,101)  (NAME2(I),I=1,40)
  READ(7,101)  (NAME3(I),I=1,40)
  READ(7,101)  (NAME4(I),I=1,40)
  READ(7,101)  (NAME5(I),I=1,40)
C-
C-
C- NFILES IS THE NUMBER OF DATA FILES TO BE REDUCED
C-
C-
C- IPRINT IS OUTPUT OPTION, 1 FOR TERMINAL 5 FOR PRINTER
C-
C-
C- IGRAF IS PLOTTING TIME INTERVAL + FOR FRQUENCY DATA - FOR FEQ &
C-  CUMULATIVE PROBABILITY
C-
```

```
C-
C- ICALC IS CALCULATION OPTION 1 FOR CONVERSION COEFF & SECTION PI
C-                                2 FOR PAIRED PI IN ADDITION
C-                                3 FOR MANEUVER CONVERSION OF SECTION
C-                                  IN ADDITION TO 1&2
C-                                4 FOR ALL ABOVE PLUS IND
C-                                  PAIRED MAN CONV
C-                  5 FOR SECTION DATA ONLY (ALL COMPUTATIONS)
C- DELTA IS GRID SIZE FOR CONTINUOUS COMPUTATIONS IN RANGE OF\\
   \\ +/-100
C-
C- ICOMP IS THE FREQUENCY OF DATA COMPUTATION IN INTEGER SECONDS
C- NAME1 IS THE TITLE FOR FREQUENCY DATA GRAPH
C- NAME2 IS THE TITLE FOR PERFORMANCE INDEX GRAPH
C-NAME3 IS THE TITLE FOR CUMULATIVE PROBABILITY GRAPH
C-NAME4 IS THE TITLE FOR CONVERSION COEFFICIENT GRAPHS
C- NAME5 IS THE TITLE FOR TIME IN STATE GRAPHS
C- N IS NUMBER OF PTS IN SECTION FILES--IT HAS NFILES VALUES
C- NPAIR IS THE NUMBER OF POINTS IN PAIRED FILES IT HAS
C-                      2.*NFILES VALUES
C-                      FOR A 2 V 1 ENGAGEMENT
C- PIS ARE THE SECTION PERFORMANCE INDICES IT HAS N(I) VALUES
C-                      PER DATA FILE
C- ISTATS ARE THE MANEUVER CONVERSION STATES--N(I) VALUES PER FILE
C-                      1=OFF WEAPONS
C-                      2=OFFENSIVE
C-                      3=NEUTRAL
C-                      4=DEFENSIVE
C-                      5=DEF FATAL
C-                      6=UTRADEOFF
C- CONCO ARE THE CONVERSION COEFFICIENTS N(I) VALUES PER FILE
C- PIPAIR ARE THE PAIRED PERF INDEX VALUES NPAIR(I) VALES PER PAIR
C-                        PER FILE
C-  ISTATP ARE THE PAIRED STATE DATA SAME AS ISTATS BUT NO 6
C- SECTIT A TITLE FOR SECTION,PARTIT-A TITLE FOR PAIRS
 DO 200 I=1,NFILES
 READ(2,/) N(I)
 JK=N(I)/10
 KJ=JK*10
 READ(2,/) (PIS(I,J),J=1,N(I))
 IF(KJ.EQ.N(I)) READ(2,300) BLANK
 READ(2,300) (SECTIT(I,J),J=1,70)
 READ(2,300) (SECTIT(I,J),J=71,140)
 READ(2,/) (ISTATS(I,J),J=1,N(I))
 READ(2,/) (CONCO(I,J),J=1,N(I))
 200 CONTINUE
 WRITE(1,310)
 310 FORMAT("I JUST READ ALL THE SECTION DATA")
 IF(ICALC.EQ.1.OR.ICALC.EQ.5) GO TO 500
 DO 400 I=1,NFILES
 READ(3,/) NPAIR(I)
 READ(3,300) (PARTIT(I,J),J=1,70)
 READ(3,/) (PIPAIR(I,J),J=1,NPAIR(I))
 READ(3,/) (ISTATP(I,J),J=1,NPAIR(I))
 400 CONTINUE
 WRITE(1,320)
 320 FORMAT("I JUST READ PAIR A DATA")
 DO 500 I=1,NFILES
 K=I+NFILES
```

```
READ(6,/) NPAIR(K)
READ(6,300) (PARTIT(K,J),J=1,70)
READ(6,/) (PIPAIR(K,J),J=1,NPAIR(K))
READ(6,/) (ISTATP(K,J),J=1,NPAIR(K))
500 CONTINUE
WRITE(1,330)
330 FORMAT("I JUST READ PAIR B DATA")
300 FORMAT(70A1)
WRITE(1,332)
332 FORMAT("DATA ARE IN")
WRITE(IPRINT,410)
410 FORMAT(1H1,2X,"THE FOLLOWING DATA IS USED IN THIS RUN")
WRITE(IPRINT,300) ((SECTIT(I,J),J=1,140),I=1,NFILES)
NBIG=0
NPBIG=0
DO 501 I=1,NFILES
IF(N(I).GT.NBIG) NBIG=N(I)
IF(NPAIR(I).GT.NPBIG) NPBIG=NPAIR(I)
501 CONTINUE
NPTS=200./DELTA+1
C-
C-
C- SECTION INDEX FREQUENCY DISTRIBUTIONS IN TIME
C-
C-
DO 600 I=1,NBIG,ICOMP
KSET=I
K=0
DO 550 J=1,NFILES
IF(N(J).LT.I) GO TO 550
K=K+1
A(K)=PIS(J,I)
KPIS(I)=K
B(K)=CONCO(J,I)
550 CONTINUE
IF(K.LT.10) GO TO 610
CALL FREDIS(-100.,100.,DELTA,A,K,FREQ,CUMP,ANS)
DO 570 J=1,NPTS
FPIS(I,J)=FREQ(J)
570 CUMPIS(I,J)=CUMP(J)
PISMN(I)=ANS(1)
PISDEV(I)=ANS(2)
PISM3(I)=ANS(3)
PISM4(I)=ANS(4)
CALL FREDIS(-100.,100.,DELTA,B,K,FREQ,CUMP,ANS)
DO 580 J=1,NPTS
FCC(I,J)=FREQ(J)
580 CUMPCC(I,J)=CUMP(J)
CCMN(I)=ANS(1)
CCDEV(I)=ANS(2)
CCM3(I)=ANS(3)
CCM4(I)=ANS(4)
600 CONTINUE
GO TO 620
610 KSET=I-ICOMP
620 CONTINUE
WRITE(1,333) KSET
333 FORMAT("I JUST FINISHED SECTION FREQ DATA FOR",I3," PTS")
IF(ICALC.EQ.1.OR.ICALC.EQ.5) GO TO 920
```

```
C-
C-
C-  CALCULATE PAIRED INFORMATION FREQUENCY DATA
C-
C-
 DO 800 I=1,NPBIG,ICOMP
 KPARLS=I
 K=0
 KQ=NFILES*2
 DO 650 J=1,KQ
 IF(NPAIR(J).LT.I) GO TO 650
 K=K+1
 A(K)=PIPAIR(J,I)
 KIPAIR(I)=K
 650 CONTINUE
 IF(K.LT.10) GO TO 810
 CALL FREDIS(-100.,100.,DELTA,A,K,FREQ,CUMP,ANS)
 DO 770 J=1,NPTS
 FPIP(I,J)=FREQ(J)
 770 CUMPIP(I,J)=CUMP(J)
 PIPMN(I)=ANS(1)
 PIPDEV(I)=ANS(2)
 PIPM3(I)=ANS(3)
 PIPM4(I)=ANS(4)
 800 CONTINUE
 GO TO 820
 810 KPARLS=I-ICOMP
 820 CONTINUE
 WRITE(1,334) KPARLS
 334 FORMAT("I JUST FINISHED PAIRED FREQ DATA FOR",I3," PTS")
C-
C-
C-   CALCULATE SECTION MANEUVER CONVERSION DATA
C-
C-
 IF(ICALC.LT.3) GO TO 1201
 DO 850 I=1,6
 DO 850 J=1,6
 CPS(I,J)=0.
 850 NCS(I,J)=0.
 DO 900 I=1,NFILES
 NN=N(I)-1
 DO 900 J=1,NN
 IF(ISTATS(I,J).LE.0.OR.ISTATS(I,J+1).LE.0) GO TO 900
 IF(ISTATS(I,J).EQ.ISTATS(I,J+1)) GO TO 900
 IDEX=ISTATS(I,J)
 JDEX=ISTATS(I,J+1)
 NCS(IDEX,JDEX)=NCS(IDEX,JDEX)+1
 900 CONTINUE
 DO 1000 I=1,6
 TC(I)=0.
 DO 1000 J=1,6
 1000 TC(I)=NCS(I,J)+TC(I)
```

```
DO 1200 I=1,6
DO 1200 J=1,6
IF(I.EQ.J) GO TO 1200
IF(TC(I).LT.0.5) CPS(I,J)=0.
IF(TC(I).LT.0.5) GO TO 1200
CPS(I,J)=NCS(I,J)/TC(I)
1200 CONTINUE
1201 CONTINUE
WRITE(1,335)
335 FORMAT("I JUST FINISHED SECTION MANEUVER CONV DATA")
C-
C-
C-   CALCULATE TIME IN STATE DISTRIBUTION
C-
C-
IF(ICALC.LT.3) GO TO 2702
DO 1600 I=1,6
IFL(I)=1
DO 1600 J=1,300
1600 ITIS(I,J)=0.
DO 1800 I=1,NFILES
NN=N(I)-1
DO 1800 J=1,NN
M=ISTATS(I,J)
L=IFL(M)
IF(ISTATS(I,J).EQ.ISTATS(I,J+1)) GO TO 1750
IFL(M)=IFL(M)+1
1750 ITIS(M,L)=ITIS(M,L)+1
IF(J.EQ.NN.AND.ISTATS(I,J).EQ.ISTATS(I,J+1)) ITIS(M,L)=0.
IF(ITIS(M,L).EQ.0) IFL(M)=IFL(M)-1
1800 CONTINUE
TMAX=0.
DO 2000 I=1,6
NN=IFL(I)
TMAX=0.
DO 1850 J=1,NN
A(J)=ITIS(I,J)
1850 IF(ITIS(I,J).GT.TMAX) TMAX=ITIS(I,J)
IF(TMAX.LT.0.5) GO TO 2050
DEL=TMAX/50.
DO 1900 K=1,51
1900 TSCALE(I,K)=(K-1)*DEL
IF(NN.LT.3) GO TO 2050
CALL FREDIS(0.,TMAX,DEL,A,NN,FREQ,CUMP,ANS)
DO 1950 K=1,51
TFREQ(I,K)=FREQ(K)
1950 TCUMP(I,K)=CUMP(K)
TMEAN(I)=ANS(1)
TDEV(I)=ANS(2)
TMOM3(I)=ANS(3)
TMOM4(I)=ANS(4)
GO TO 2000
```

```
2050 CONTINUE
DO 2060 K=1,51
TSCALE(I,K)=0.
TFREQ(I,K)=0.
2060 TCUMP(I,K)=0.
TMEAN(I)=0.
TDEV(I)=0.
TMOM3(I)=0.
TMOM4(I)=0.
2000 CONTINUE
WRITE(1,2001)
2001 FORMAT("I JUST FINISHED SECTION TIME IN STATE")
C-
C-
C- CALCULATE PAIRED MANEUVER CONVERSION DATA
C-
C-
IF(ICALC.NE.4) GO TO 2702
DO 2100 I=1,5
DO 2100 J=1,5
CPP(I,J)=0.
2100 NCP(I,J)=0
NX=2.*NFILES
DO 2200 I=1,NX
NN=NPAIR(I)-1
DO 2200 J=1,NN
IF(ISTATP(I,J).LE.0.OR.ISTATP(I,J+1).LE.0) GO TO 2200
IF(ISTATP(I,J).EQ.ISTATP(I,J+1)) GO TO 2200
IDEX=ISTATP(I,J)
JDEX=ISTATP(I,J+1)
NCP(IDEX,JDEX)=NCP(IDEX,JDEX)+1
2200 CONTINUE
DO 2300 I=1,5
TC(I)=0.
DO 2300 J=1,5
2300 TC(I)=TC(I)+NCP(I,J)
DO 2400 I=1,5
DO 2400 J=1,5
IF(I.EQ.J) GO TO 2400
IF(TC(I).LT.0.5) CPP(I,J)=0.
IF(TC(I).LT.0.5) GO TO 2400
CPP(I,J)=NCP(I,J)/TC(I)
2400 CONTINUE
WRITE(1,2401)
2401 FORMAT("I JUST FINISHED PAIRED MAN CONV")
C- C-
C-
C- CALCULATE TIME IN STATE FOR PAIRS
C-
C-
DO 2500 I=1,5
IFM(I)=1
DO 2500 J=1,300
2500 ITIP(I,J)=0
DO 2600 I=1,NX
NN=NPAIR(I)-1
```

```
DO 2600 J=1,NN
M=ISTATP(I,J)
L=IFM(M)
IF(ISTATP(I,J).EQ.ISTATP(I,J+1)) GO TO 2550
IFM(M)=IFM(M)+1
2550 ITIP(M,L)=ITIP(M,L)+1
IF(J.EQ.NN.AND.ISTATP(I,J).EQ.ISTATP(I,J+1)) ITIP(M,L)=0
IF(ITIP(M,L).EQ.0) IFM(M)=IFM(M)-1
2600 CONTINUE
TMAX=0.
DO 2700 I=1,5
NN=IFM(I)
TMAX=0.
DO 2610 J=1,NN
A(J)=ITIP(I,J)
2610 IF(ITIP(I,J).GT.TMAX) TMAX=ITIP(I,J)
IF(TMAX.LT.0.5) GO TO 2655
DEL=TMAX/50.
DO 2620 K=1,51
2620 TPCALE(I,K)=(K-1)*DEL
IF(NN.LT.3) GO TO 2655
CALL FREDIS(0.,TMAX,DEL,A,NN,FREQ,CUMP,ANS)
DO 2650 K=1,51
TPFREQ(I,K)=FREQ(K)
2650 TPCUMP(I,K)=CUMP(K)
TPMEAN(I)=ANS(1)
TPDEV(I)=ANS(2)
TPMOM3(I)=ANS(3)
TPMOM4(I)=ANS(4)
GO TO 2700
2655 CONTINUE
DO 2656 K=1,51
TPFREQ(I,K)=0.
TPCUMP(I,K)=0.
2656 TPCALE(I,K)=0.
TPMEAN(I)=0.
TPDEV(I)=0.
TPMOM3(I)=0.
TPMOM4(I)=0.
2700 CONTINUE
2702 CONTINUE
WRITE(1,2701)
2701 FORMAT("I JUST FINISHED PAIRED TIME IN STATE-OUTPUT BEGINS")
C-
C- BEGIN OUTPUT OF THE COMPUTED DATA
C-
C- THE COMPUTED DISTRIBUTION OF THE SECTION PERF INDICES
C-
```

```
DO 7950 J=1,NPTS
7950 MXX(J)=-100.+(J-1)*DELTA
WRITE(IPRINT,3000)
3000 FORMAT(1H1,2X,"PERFORMANCE INDICES DISTRIBUTION")
NMXPT=NPTS/10
NMXPT=NMXPT*10
DO 9000 KQ=1,NMXPT,10
KQ9=KQ+9
WRITE(IPRINT,8001) (MXX(I),I=KQ,KQ9)
8001 FORMAT(2X,"TIME  FREQ(",I4,")  FREQ(",I4,")  FREQ(",
-I4,")  FREQ(",I4,")  FREQ(",I4,")  FREQ(",I4,")  FREQ(",
-I4,")  FREQ(",I4,")  FREQ(",I4,")  FREQ(",I4,")")
DO 9000 J=1,KSET,ICOMP
WRITE(IPRINT,8950) J,(FPIS(J,K),K=KQ,KQ9)
8950 FORMAT(2X,I4,F12.5,9F12.5)
9000 CONTINUE
NR=NMXPT+1
WRITE(IPRINT,8001) (MXX(I),I=NR,NPTS)
DO 9001 J=1,KSET,ICOMP
WRITE(IPRINT,8950) J,(FPIS(J,K),K=NR,NPTS)
9001 CONTINUE
WRITE(IPRINT,8975)
8975 FORMAT(1H1,2X,"SUMMARY STATISTICS FOR PERF INDICES DIST")
WRITE(IPRINT,9002)
9002 FORMAT(2X,"TIME   NPTS    MEAN    VARIANCE      3RDMOM",
-"     4THMOM")
DO 9004 I=1,KSET,ICOMP
WRITE(IPRINT,9003) I,KPIS(I),PISMN(I),PISDEV(I),PISM3(I),PISM4(I)
9004 CONTINUE
9003 FORMAT(2X,I4,I7,F7.2,F10.2,F12.2,F14.2)
DO 10000 J=1,KSET,IGRAF
WRITE(4,9200) J
9200 FORMAT("TIME ",I4)
BACKSPACE 4
READ(4,9205) (NAME2(I),I=31,40)
9205 FORMAT(10A1)
DO 9500 K=1,NPTS
B(K)=CUMPIS(J,K)
9500 A(K)=FPIS(J,K)
CALL PLOT(MXX,A,NPTS,IPRINT,NAME2,NAME1)
IF(GRAFOP.EQ.-1) CALL PLOT(MXX,B,NPTS,IPRINT,NAME2,NAME3)
10000 CONTINUE
WRITE(1,2999)
2999 FORMAT(" PISECT IS OUT")
C-
C- THE COMPUTED DISTRIBUTION OF THE CONVERSION COEFFICIENTS
C-
WRITE(IPRINT,3000)
3000 FORMAT(1H1,2X,"CONVERSION COEFFICIENT DISTRIBUTION")
DO 3100 KQ=1,NMXPT,10
KQ9=KQ+9
WRITE(IPRINT,8001) (MXX(I),I=KQ,KQ9)
```

```
DO 3100 J=1,KSET,ICOMP
WRITE(IPRINT,8950) J,(FCC(J,K),K=KQ,KQ9)
3100 CONTINUE
WRITE(IPRINT,8001) (MXX(I),I=NR,NPTS)
DO 3101 J=1,KSET,ICOMP
WRITE(IPRINT,8950) J,(FCC(J,K),K=NR,NPTS)
3101 CONTINUE
WRITE(IPRINT,3120)
3120 FORMAT(1H1,2X,"SUMMARY STATISTICS FOR CONVERSION COEFF")
WRITE(IPRINT,9002)
DO 3102 I=1,KSET,ICOMP
WRITE(IPRINT,9003) I,KPIS(I),CCMN(I),CCDEV(I),CCM3(I),CCM4(I)
3102 CONTINUE
DO 3200 J=1,KSET,IGRAF
WRITE(4,9200) J
BACKSPACE 4
READ(4,9205) (NAME4(I),I=31,40)
DO 3150 K=1,NPTS
B(K)=CUMPCC(J,K)
3150 A(K)=FCC(J,K)
CALL PLOT(MXX,A,NPTS,IPRINT,NAME4,NAME1)
IF(GRAFOP.EQ.-1) CALL PLOT(MXX,B,NPTS,IPRINT,NAME4,NAME3)
3200 CONTINUE
WRITE(1,3201)
3201 FORMAT("CONV COEFF IS OUT")
IF(ICALC.NE.1.AND.ICALC.NE.4) GO TO 3603
C-
C- THE COMPUTED DISTRIBUTION OF THE PAIRED PERFORMANCE INDICES
C-
WRITE(IPRINT,3300)
3300 FORMAT(1H1,2X,"PAIRED PERFORMANCE INDICES DISTRIBUTION")
DO 3400 KQ=1,NMXPT,10
KQ9=KQ+9
WRITE(IPRINT,8001) (MXX(I),I=KQ,KQ9)
DO 3400 J=1,KPARLS,ICOMP
WRITE(IPRINT,8950) J,(FPIP(J,K),K=KQ,KQ9)
3400 CONTINUE
WRITE(IPRINT,8001) (MXX(I),I=NR,NPTS)
DO 3401 J=1,KPARLS,ICOMP
WRITE(IPRINT,8950) J,(FPIP(J,K),K=NR,NPTS)
3401 CONTINUE
WRITE(IPRINT,9002)
DO 3402 I=1,KPARLS,ICOMP
WRITE(IPRINT,9003) I,KIPAIR(I),PIPMN(I),PIPDEV(I),PIPM3(I),
-PIPM4(I)
3402 CONTINUE
DO 3600 J=1,KPARLS,IGRAF
WRITE(4,9200) J
BACKSPACE 4
READ(4,9205) (NAME2(I),I=31,40)
DO 3550 K=1,NPTS
B(K)=CUMPIP(J,K)
3550 A(K)=FPIP(J,K)
```

```
CALL PLOT(MXX,A,NPTS,IPRINT,NAME2,NAME1)
IF(GRAFOP.EQ.-1) CALL PLOT(MXX,B,NPTS,IPRINT,NAME2,NAME3)
3600 CONTINUE
3603 CONTINUE
WRITE(1,3601)
3601 FORMAT("PI PAIR IS OUT")
IF(ICALC.LT.3) GO TO .3683
WRITE(IPRINT,3604)
3604 FORMAT(1H1,2X,"SECTION MANEUVER CONVERSION/CONVERSION",
-" PROBABILITY MATRIX")
WRITE(IPRINT,3608)
3608 FORMAT(15X,"OFF WEP   OFFENSIVE NEUTRAL   DEFENSIVE ",
-"DEF FAT   TRADEOFF")
WRITE(IPRINT,3610) (CPS(1,J),J=2,6)
3610 FORMAT(2X,"OFF WEP          •",5X,5F10.4)
WRITE(IPRINT,3612) CPS(2,1),(CPS(2,J),J=3,6)
3612 FORMAT(2X,"OFFENSIVE ",F10.4,4X,"•",5X,4F10.4)
WRITE(IPRINT,3614) (CPS(3,J),J=1,2),(CPS(3,J),J=4,6)
3614 FORMAT(2X,"NEUTRAL . ",2F10.4,4X,"•",5X,3F10.4)
WRITE(IPRINT,3616) (CPS(4,J),J=1,3),(CPS(4,J),J=5,6)
3616 FORMAT(2X,"DEFENSIVE ",3F10.4,4X,"•",5X,2F10.4)
WRITE(IPRINT,3618) (CPS(5,J),J=1,4),CPS(5,6)
3618 FORMAT(2X,"DEF FAT   ",4F10.4,4X,"•",5X,F10.4)
WRITE(IPRINT,3620) (CPS(6,J),J=1,5)
3620 FORMAT(2X,"TRADEOFF  ",5F10.4,4X,"•")
WRITE(IPRINT,3622)
3622 FORMAT(1H1,2X,"SECTION TIME IN STATE DISTRIBUTION")
WRITE(IPRINT,3624)
3624 FORMAT(8X,"TIME  FREQ(OFFWEP)  TIME  FREQ(OFFNSV)"
-"  TIME  FREQ(NEUTRL)  TIME  FREQ(DEFNSV)  TIME FREQ(DEFFAT)",
-"  TIME  FREQ(TRADE )  ")
DO 3650 J=1,51
WRITE(IPRINT,3626) ((TSCALE(I,J),TFREQ(I,J)),I=1,6)
3626 FORMAT(2X,6(F10.2,F10.4))
3650 CONTINUE
WRITE(IPRINT,3628)
3628 FORMAT(1H1,4X,"SUMMARY STATISTICS FOR SECTION MANEUVER\\
   \\ CONV")
WRITE(IPRINT,3630)
3630 FORMAT(2X,"STATE      MEAN       VARIANCE"
-," 3RDMOM       4THMOM       NPTS")
WRITE(4,3655)
3655 FORMAT("OFF WEP"/"OFFENSIVE"/"NEUTRAL"/"DEFENSIVE"/"DEF\\
   \\ FAT"/
-"TRADE OFF")
DO 3654 J=1,6
3654 BACKSPACE 4
DO 3660 J=1,6
READ(4,3657) ANNA,KING
3657 FORMAT(2A5)
WRITE(IPRINT,3662) ANNA,KING,TMEAN(J),TDEV(J),TMOM3(J),TMOM4(J)
-,IFL(J)
3662 FORMAT(2X,2A5,4F10.2,I7)
3660 CONTINUE
DO 3665 J=1,6
3665 BACKSPACE 4
```

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DO 3680 I=1,6
DO 3670 J=1,51
A(J)=TFREQ(I,J)
3670 B(J)=TSCALE(I,J)
READ(4,3656) (NAMES(K),K=31,40)
3656 FORMAT(10A1)
CALL PLOT(B,A,51,IPRINT,NAME5,NAME1)
IF(GRAFOP.NE.-1) GO TO 3680
DO 3675 J=1,51
3675 A(J)=TCUMP(I,J)
CALL PLOT(B,A,51,IPRINT,NAME5,NAME3)
3680 CONTINUE
3683 CONTINUE
WRITE(1,3681)
3681 FORMAT("SECT MN CNV IS OUT")
IF(ICALC.NE.4) GO TO 3800
WRITE(IPRINT,3682)
3682 FORMAT(1H1,2X,"PAIRED MANEUVER CONVERSION PROBABILITY",
-" MATRIX")
WRITE(IPRINT,3608)
WRITE(IPRINT,3610) (CPP(1,J),J=2,5)
WRITE(IPRINT,3612) CPP(2,1),(CPP(2,J),J=3,5)
WRITE(IPRINT,3614) (CPP(3,J),J=1,2),(CPP(3,J),J=4,5)
WRITE(IPRINT,3616) (CPP(4,J),J=1,3),(CPP(4,J),J=5,5)
WRITE(IPRINT,3618) (CPP(5,J),J=1,4)
WRITE(IPRINT,3684)
3684 FORMAT(1H1,2X"PAIRED TIME IN STATE DISTRIBUTIONS")
WRITE(IPRINT,3624)
DO 3686 J=1,51
WRITE(IPRINT,3626) ((TPCALE(I,J),TPFREQ(I,J)),I=1,5)
3686 CONTINUE
WRITE(IPRINT,3687)
WRITE(IPRINT,3630)
WRITE(4,3655)
DO 3689 J=1,6
3689 BACKSPACE 4
3687 FORMAT(1H1,2X,"SUMMARY STATISTICS FOR PAIRED TIME IN STATE")
DO 3690 J=1,5
READ(4,3657) ANNA,KING
WRITE(IPRINT,3662) ANNA,KING,TPMEAN(J),TPDEV(J),TPMOM3(J)
-,TPMOM4(J),IFM(J)
3690 CONTINUE
DO 3691 J=1,5
3691 BACKSPACE 4
```

```
DO 3698 I=1,5
DO 3692 J=1,51
A(J)=TPFREQ(I,J)
3692 B(J)=TPCALE(I,J)
READ(4,3656) (NAMES(K),K=31,40)
CALL PLOT(B,A,51,IPRINT,NAMES,NAME1)
IF(GRAFOP.NE.-1) GO TO 3698
DO 3694 J=1,51
3694 A(J)=TPCUMP(I,J)
CALL PLOT(B,A,51,IPRINT,NAMES,NAME3)
3698 CONTINUE
3800 CONTINUE
WRITE(1,3699)
3699 FORMAT("ALL DATA ARE OUT")
C-
C- START OUTPUT OF EXPECTED PATHS
C-
DO 4005 I=1,101
A(I)=BLANK
4005 B(I)=BLANK
DO 4000 J=1,101,10
B(J)=PLUS
A(J)=DOT
4000 CONTINUE
WRITE(IPRINT,4001)
4001 FORMAT(1H1,2X,"EXPECTED PATHS FOR CONTINUOUS DATA"///
-10X," * PERFORMANCE INDEX SECTION"/
-10X," + PERFORMANCE INDEX PAIRS"/
-10X," $ CONVERSION COEFFICIENT SECTION"/
-//8X,"-100       -80       -60       -40       -20
-"0        +20       +40       +60       +80       +100")
WRITE(IPRINT,4002) (B(J),J=1,101),(A(J),J=1,101)
4002 FORMAT(2X,"TIME",4X,101A1/2X,"SECS",4X,101A1)
DO 4100 J=1,101
4100 B(J)=PLUS
WRITE(IPRINT,4101) (B(J),J=1,101)
4101 FORMAT(10X,101A1)
IF(ICALC.EQ.1.OR.ICALC.EQ.5) KPARLS=KSET
DO 5000 J=1,KPARLS,ICOMP
DO 4003 I=1,101
4003 A(I)=BLANK
A(51)=DOT
A(1)=PLUS
A(101)=PLUS
IF(J.GT.KSET) GO TO 4004
K=0.50*CCMN(J)+50.5
IF(K.GE.1.AND.K.LE.101) A(K)=DOLL
L=0.50*PISMN(J)+50.5
IF(L.GE.1.AND.L.LE.101) A(L)=STAR
4004 M=0.50*PIPMN(J)+50.5
IF(M.GE.1.AND.M.LE.101) A(M)=PLUS
WRITE(IPRINT,4006) J,(A(KK),KK=1,101)
4006 FORMAT(3X,I4,3X,101A1)
5000 CONTINUE
CALL EXIT
END
```

```
 SUBROUTINE FREDIS(ALPHA,BETA,DELTA,X,NDATA,FREQ,CUMP,ANS)
C-
C- THIS SUBROUTINE USES FREQUENCY DISTRIBUTION
C-  RECOVERY TECHNIQUE---*** PER ULTRASYSTEMS RPT
C-
C- IT CALLS AN INTEGRATION SUBROUTINE (QSF) AND A MOMENT\\
   \\ CALCULATION
C-  SUBROUTINE (MOMEN)
C-
C- THE DISTRIBUTION FUNCTION OF THE X STRING VECTOR IS COMPUTED
C-  AND PLACED IN FREQ AFTER IT IS NORMALIZED
C-
C- X HAS NDATA VALUES WITH A MAXIMUM OF BETA (RANGE VALUE)
C- A MINIMUM OF ALPHA (RANGE VALUE) TO BE COMPUTED OVER
C- A GRID VALUE OF DELTA
C-
C- THE PROGRAM ALSO RETURNS THE NORMALIZED CUMULATIVE PROBABILITY
C-     OF OCCURENCE (CUMP) AND THE FIRST FOUR MOMENTS (ANS)
C-
 DIMENSION\\
   \\ UBO(5),ANS(4),X(500),FREQ(500),CUMP(500),Y(500),XI(500),
-FHAT(500),U(500)
 DIMENSION NX(500),RF(500)
 UBO(1)=ALPHA
 UBO(2)=BETA
 UBO(3)=DELTA
 SUM1=0.
 SUM2=0.
 NPTS=(BETA-ALPHA)/DELTA+1
 SUMAIJ=0.
 NINT=(BETA-ALPHA)/DELTA
 DO 10 I=1,NDATA
 DO 10 J=1,NDATA
 10 SUMAIJ=(X(I)-X(J))**2+SUMAIJ
 XMU=0.
 XMU=SUMAIJ
 XMU=XMU/(NDATA*(NDATA-1))
 IF(ABS(XMU).LT.1.E-08) RHO=0.
 IF(ABS(XMU).LT.1.E-08) GO TO 22
 IF(XMU.GT.1.) DELTA1=0.010
 IF(XMU.GT.1.) RHO=(DELTA1*ALOG(NDATA)+ALOG(XMU))/XMU
 IF(XMU.LE.1.) DELTA1=0.250
 IF(XMU.LE.1.) RHO=DELTA1*ALOG(NDATA)/XMU
 22 CONTINUE
 BINV=0.
 DO 30 I=1,NDATA
 DO 30 J=1,NDATA
 ECH=EXP(-1.*RHO*(X(I)-X(J))**2)
 FUNC=(X(I)-X(J))**2*ECH
 30 BINV=BINV+FUNC
 IF(ABS(BINV).LT.1.E-08) B=0.
 IF(ABS(BINV).LT.1.E-08) GO TO 32
 BINV=BINV/(NDATA*(NDATA-1))
 B=1./BINV
 32 CONTINUE
```

```
DO 40 I=1,NPTS
40 Y(I)= ALPHA+(I-1)*DELTA
DO 50 I=1,NPTS
FHAT(I)=0.
DO 50 J=1,NDATA
STEP1=Y(I)-X(J)
STEP2=EXP(-1*(B*STEP1)**2/2.)
50 FHAT(I)=FHAT(I)+B/NDATA*STEP2
CALL QSF(DELTA,FHAT,XI,NPTS)
DO 500 J=1,NPTS
IF(ABS(XI(NPTS)).GT.1.E-08) GO TO 490
FREQ(J)=0.
CUMP(J)=0.
GO TO 500
490 FREQ(J)=FHAT(J)/XI(NPTS)
CUMP(J)=XI(J)/XI(NPTS)
500 CONTINUE
CALL MOMEN(FREQ,UBO,NPTS,ANS)
RETURN
END
```

```
      SUBROUTINE QSF(H,Y,Z,NDIM)
C- THIS IS A GENERAL INTEGRATION ROUTINE FOR EQUALLY SPACED
C-  FUNCTIONS (Y)
C-
C- THE SPACING OF Y IS H--- THE NUMBER OF POINTS IS NDIM
C- THE INTEGRAL OF Y IS Z
C-
C- THE SUBROUTINE USES A COMBINATION OF SIMPSONS RULE
C- AND NEWTONS THREE-EIGHTHS RULE
C-
      DIMENSION Y(1),Z(1)
      HT=H*1./3.
      1 SUM1=Y(2)+Y(2)
      SUM1=SUM1+SUM1
      SUM1=HT*(Y(1)+SUM1+Y(3))
      AUX1=Y(4)+Y(4)
      AUX1=AUX1+AUX1
      AUX1=SUM1+HT*(Y(3)+AUX1+Y(5))
      AUX2=HT*(Y(1)+3.875*(Y(2)+Y(5))+2.625*(Y(3)+Y(4))+Y(6))
      SUM2=Y(5)+Y(5)
      SUM2=SUM2+SUM2
      SUM2=AUX2-HT*(Y(4)+SUM2+Y(6))
      Z(1)=0.
      AUX=Y(3)+Y(3)
      AUX=AUX+AUX
      Z(2)=SUM2-HT*(Y(2)+AUX+Y(4))
      Z(3)=SUM1
      Z(4)=SUM2
      IF(NDIM-6) 5,5,2
      2 DO 4 I=7,NDIM,2
      SUM1=AUX1
      SUM2=AUX2
      AUX1=Y(I-1)+Y(I-1)
      AUX1=AUX1+AUX1
      AUX1=SUM1+HT*(Y(I-1)+AUX1+Y(I))
      Z(I-2)=SUM1
      IF(I-NDIM)3,6,6
      3 AUX2=Y(I)+Y(I)
      AUX2=AUX2+AUX2
      AUX2=SUM2+HT*(Y(I-1)+AUX2+Y(I+1))
      4 Z(I-1)=SUM2
      5 Z(NDIM-1)=AUX1
      Z(NDIM)=AUX2
      RETURN
      6 Z(NDIM-1)=SUM2
      Z(NDIM)=AUX1
      RETURN
      END
```

```
SUBROUTINE MOMEN(F,UBO,NPTS,ANS)
C-
C- THIS ROUTINE CALCULATES THE CLASSICAL MOMENTS OF A GIVEN
C- FREQUENCY FUNCTION (F) HAVING A MAX (UBO(2)) A MIN (UBO(1))
C- AND A GRID SIZE(UBO(3)) THE MOMENTS ARE PLACED IN ANS
C-
C- THE FIRST MOMENT (MEAN IS ABOUT THE ORIGIN
C- ALL SUBSEQUENT MOMENTS ARE ABOUT THE MEAN
C-
DIMENSION F(1),ANS(1),XM(500),Y(500)
DIMENSION UBO(3)
DO 10 I=1,4
10 ANS(I)=0.
DO 20 I=1,NPTS
Y(I)=UBO(1)+(I-1)*UBO(3)
20 XM(I)=Y(I)*F(I)
CALL QSF(UBO(3),XM,XM,NPTS)
ANS(1)=XM(NPTS)
DO 30 I=1,NPTS
30 XM(I)=F(I)*(Y(I)-ANS(1))**2
CALL QSF(UBO(3),XM,XM,NPTS)
ANS(2)=XM(NPTS)
DO 40 I=1,NPTS
40 XM(I)=F(I)*(Y(I)-ANS(1))**3
CALL QSF(UBO(3),XM,XM,NPTS)
ANS(3)=XM(NPTS)
DO 50 I=1,NPTS
50 XM(I)=F(I)*(Y(I)-ANS(1))**4
CALL QSF(UBO(3),XM,XM,NPTS)
ANS(4)=XM(NPTS)
RETURN
END
```

```
SUBROUTINE PLOT(X,Y,NDATA,IPRINT,NAMEX,NAMEY)
C-
C- THIS ROUTINE PLOTS A GENERAL VECTOR Y VERSUS A GENERAL
C- VECTOR X CONSISTING OF NDATA VALUES NOT NECESSARILY ORDERED
C-
C- NAMEX IS A 40 CHARACTER IDENTIFIER OF THE X VER(ALPHANUM)
C- NAMEY  "   "   ""   """   ""   """   Y VARIABLE
C-
C- IPRINT IS THE OUTPUT LOGICAL UNIT NUMBER
C-
C- THE ROUTINE COMPUTES ITS OWN SCALE VALUES AND DEVELOPES
C- ITS OWN OUTPUT---IT RETURNS NOTHING TO THE MAIN PROGRAM
C-
 DIMENSION NAMEX(16),NAMEY(16)
 DIMENSION X(51),Y(51),PLOTS(51,51),Z1(51),Z2(51)
 DATA BLANK,STAR,XXX,PLUS/" ","*","X","+"/
 DATA DOT/"."/
 DATA DASH/"-"/
 DO 10 J=1,51
 DO 10 K=1,51
 10 PLOTS(J,K)=BLANK
 DO 11 K=1,51
 11 PLOTS(51,K)=DOT
 DO 121 J=1,51
 121 PLOTS(J,51)=DOT
 DO 131 J=1,51,5
 DO 131 K=1,51,5
 IF(J.EQ.51.OR.K.EQ.51) GO TO 130
 GO TO 131
 130 PLOTS(J,K)=DASH
 PLOTS(K,J)=DASH
 131 CONTINUE
 XBIG=-9.9E06
 XSMALL=9.9E06
 YBIG=-9.9E06
 YSMALL=9.9E06
 DO 999 I=1,NDATA
 IF(X(I).GT.XBIG.AND.Y(I).GT.(1.E-06)) XBIG=X(I)
 IF(X(I).LT.XSMALL.AND.Y(I).GT.(1.E-06)) XSMALL=X(I)
 IF(Y(I).GT.YBIG) YBIG=Y(I)
 IF(Y(I).LT.YSMALL) YSMALL=Y(I)
 999 CONTINUE
 YDEL=YBIG-YSMALL
 XDEL=XBIG-XSMALL
 IF(XDEL.LT.1.E-08.OR.YDEL.LT.1.E-08) RETURN
 TEST=1.E-07
 DO 998 I=1,14
 TEST=TEST*10.
 DO 998 J=1,9
 IF(YDEL.GT.(J*TEST).AND.YDEL.LE.((J+1)*TEST)) YDEL=(J+1)*TEST
 IF(XDEL.GT.(J*TEST).AND.XDEL.LE.((J+1)*TEST)) XDEL=(J+1)*TEST
 CONTINUE
 998 CONTINUE
```

```
XAVG=(XBIG+XSMALL)/2.
YAVG=(YBIG+YSMALL)/2.
XMIN=XAVG-XDEL/2.
XMAX=XAVG+XDEL/2.
YMIN=YAVG-YDEL/2.
YMAX=YAVG+YDEL/2.
XINC=(XMAX-XMIN)/50.
YINC=(YMAX-YMIN)/50.
DO 20 I=1,NDATA
IF(X(I).GT.XMAX) GO TO 12
IF(X(I).LT.XMIN) GO TO 13
IF(Y(I).GT.YMAX) GO TO 16
IF(Y(I).LT.YMIN) GO TO 17
K=(X(I)-XMIN)*(1./XINC)+1.
L=(Y(I)-YMIN)*(1./YINC)+1.
PLOTS(L,K)=STAR
GO TO 20
12 K=51
IF(Y(I).LT.YMIN) L=1
IF(Y(I).GT.YMAX) L=51
IF (Y(I).LT.YMIN.OR.Y(I).GT.YMAX) GO TO 19
L=(Y(I)-YMIN)*(1./YINC)+1.
GO TO 19
13 K=1
IF(Y(I).LT.YMIN) L=1
IF(Y(I).GT.YMAX) L=51
IF(Y(I).LT.YMIN.OR.Y(I).GT.YMAX) GO TO 19
L=(Y(I)-YMIN)*(1./YINC)+1.
GO TO 19
16 L=51
K=(X(I)-XMIN)*(1./XINC)+1.
GO TO 19
17 L=1
K=(X(I)-XMIN)*(1./XINC)+1.
19 PLOTS(L,K)=XXX
20 CONTINUE
DO 22 I=1,51
Z1(I)=XMIN+(I-1)*XINC
Z2(I)=YMIN+(I-1)*YINC
22 CONTINUE
WRITE (IPRINT,25)
25 FORMAT(1H1,//)
DO 30 K=1,51
I=52-K
WRITE(IPRINT,26) Z2(I),(PLOTS(I,J),J=1,51)
26 FORMAT(2X,F10.4,"  + ",51A1)
30 CONTINUE
```

```
WRITE(IPRINT,40)
40 FORMAT(15X,"+++++++++++++++++++++++++++++++++++++++++++++++\\
    \\++++")
WRITE(IPRINT,50)
50 FORMAT(16X,"+         +         +         +         +
    \\   +")
WRITE(IPRINT,45) Z1(1),Z1(11),Z1(21),Z1(31),Z1(41),Z1(51)
45 FORMAT(9X,6F10.2)
WRITE(IPRINT,46) (NAMEX(I),I=1,40),(NAMEY(I),I=1,40)
46 FORMAT(10X,"THE X VARIABLE IS  ",40A1/
-            10X,"THE Y VARIABLE IS  ",40A1)
RETURN
END
```

END QUIKLST 14.0 SEC.

TERMINOLOGY

ACM	- Acronym for Air Combat Maneuvering
ACM State	- A descriptor of the ACM situation as offensive, defensive, etc.
AIS	- Airborne Instrumentation Subsystem
Bimodal	- Having two characteristic peaks.
Bogie	- A term applied to the opposition aircraft in an engagement.
Bogie Switching	- A maneuver wherin the opposition aircraft switches his offensive press to avoid being "predictable".
Conversion Coefficient	- An analysis term computed by combining the performance index and maneuver conversion computations.
Conversion Probability	- The probability of converting from one ACM state to another.
Coordination Consistency	- The difference between unity and the standard deviation of the section coordination term.
Defensive	- A mathematical state where the subject aircraft or section is being threatened.
Distributions	- A mathematical term applied to the probable range of events and how test data covers that range.
Dominance	- A term applied when one aircraft or section is in decisive control of the engagement.
Expected Path	- The locus of expected values of a variable.
Fatal Defensive	- A mathematical state where the subject aircraft or section is in a weapons opportunity of an opponent.
"Flash Through"	- A mathematical term indicating a transient situation (extreme short duration).
Frequency Distribution	- A distribution of the frequency of occurrence of a variable as a function of the variable.
Magnitude Sum	- A method of combining paired data to yield section data.
Markov	- A mathematical term referring to a time independence occurrence of events.

Multimodal	- Having several characteristic peaks.
Maneuver Conversion Model	- An ACM analysis model made up of ACM states.
Neutral	- A mathematical state where the subject aircraft has neither an advantage nor disadvantage.
Offensive	- A mathematical state where the subject aircraft is threatening an opponent.
Offensive Weapons	- A mathematical state where the subject aircraft has a weapons opportunity on an opponent aircraft.
Paired Data	- A term applied to data generated for a specific fighter-to-target pair.
Paired Coefficient	- An analysis parameter generated for a specific fighter-to-target pair.
Performance Index	- A time variant figure-of-merit which scales the offensive value of a fighter-to-target pair or aircraft section via the product of angle, range, and energy penalty functions.
Section Data	- A term applied to data generated for a fighter or target section.
Section Coefficient	- An analysis parameter for a fighter or target section.
Section Coordination	- An analysis parameter which accounts for the relative contribution of each aircraft in the section.
Semi-Markov	- A Markov process modified to include a time dependence only within a given state.
Significance Level	- A mathematical term representing a minimum acceptable tactical advantage or maximum acceptable disadvantage.
State	- See ACM State.
Stochastic	- A mathematical term applied to a time dependent occurrence of events that are statistical in nature.
"Survival Sting"	- A term applied to a shortened tracking solution due to the tactical press of an opponent.
Target Aircraft	- An opponent aircraft; a bogie.

Trade Off	- An ACM state where, in a section, the offensive weapons and defensive fatal states exist simultaneously.
Trade Off Ratio	- The ratio of opponent aircraft shot down to friendly aircraft lost.
Trimodal	- Having three characteristic peaks.
Vector Sum	- A method of combining paired information.

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